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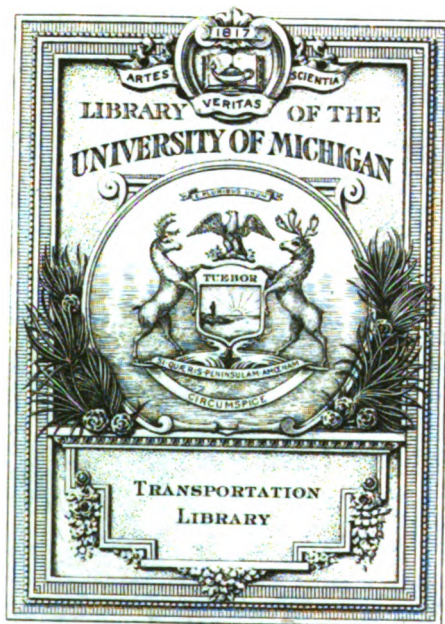
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THE
BELL TELEPHONE



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ALEXANDER GRAHAM BELL

FROM A PHOTOGRAPH TAKEN IN 1876, THE YEAR IN WHICH
THE TELEPHONE WAS PATENTED.

THE BELL TELEPHONE

The Deposition

.. OF ..

ALEXANDER GRAHAM BELL

IN THE SUIT BROUGHT BY THE UNITED STATES

TO

Annul the Bell Patents

PRINTED BY THE
AMERICAN BELL TELEPHONE COMPANY
BOSTON
1908

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INTRODUCTORY MEMORANDUM.

A United States patent was granted to Alexander Graham Bell March 7, 1876, covering broadly the electrical transmission of speech. Another patent, covering important mechanical features of apparatus for transmitting speech, was granted to Mr. Bell January 30, 1877. Many other patents have been granted to Mr. Bell, but the two just specified are those known as "The Bell Patents."

Mr. Bell's inventions were put into commercial use in the summer of 1877, and in the latter part of that year the American Speaking Telephone Company was organized by the Western Union Telegraph Company to put out telephones manufactured under patents controlled by the Western Union.

A suit commonly known as the *Dowd* case was brought in Massachusetts in September, 1878, against Dowd, an agent of the American Speaking Telephone Company, and was defended by the Western Union Telegraph Company. After voluminous evidence for both parties had been taken, counsel for the Western Union Company advised his client that the Bell patents were valid and had been infringed, and the case was settled by the parties. As a part of the settlement a decree was entered in the *Dowd* case that the Bell patents were valid and had been infringed.

In the *Dowd* case Mr. Bell made a deposition in July, 1879, in which he gave the history of his invention of the electric speaking telephone, and he was cross-examined at length. His deposition in the *Dowd* case makes about 100 pages of print.

In subsequent litigation Mr. Bell's deposition in the *Dowd* case was used by agreement of counsel, until the suit against the People's Telephone Company, in the Southern District of New York, commonly called the *Drawbaugh* case, in which the defendants relied chiefly upon the claims of Daniel Drawbaugh. Mr. Bell's deposition in the *Dowd* case was stipulated into the *Drawbaugh* case, and was supplemented by a cross-examination lasting several weeks in February and

March, 1883, increasing the original deposition by about 125 pages of print. Mr. Bell's depositions in the *Dowd* and *Drawbaugh* cases are frequently referred to in the deposition following.

In July, 1885, after the Bell patents had been sustained by a number of Circuit Court decisions, and after some of the earlier telephone cases had been appealed to the Supreme Court of the United States, certain interests hostile to the Bell patents applied to the Attorney General of the United States asking that suit be brought, in the name of the United States, to cancel the Bell patents; the applicants offering to furnish proofs that Mr. Bell was not the inventor of the telephone. As the result of this application, after numerous intermediate proceedings, a bill to cancel the Bell patents was filed in the name of the United States against the American Bell Telephone Company and Alexander Graham Bell, January 13, 1887, in the Circuit Court of the United States for the District of Massachusetts. As a part of the proofs for the defendants in this case, Mr. Bell's deposition was taken *de novo*, and he was examined and cross-examined at great length; counsel for both parties having the benefit of all previous depositions made by Mr. Bell, and of the great mass of evidence accumulated in the telephone litigation which had taken place since the issue of the Bell patents. This last deposition of Mr. Bell's is the most detailed and best arranged statement of his telephonic work. Before the taking of proofs in the Government case had been finished, the Bell patents had been sustained by the Supreme Court of the United States, and had also expired by lapse of time. The counsel in charge of the case for the Government died in the summer of 1896; and the case having been then practically abandoned by the Government, the record was never printed.

Mr. Bell's deposition is now printed by the American Bell Telephone Company because of its historical value and scientific interest, and it has seemed best to print it in full, so that the cross-examination may make evident what the opponents of the patents regarded as the vulnerable features.

Mr. Bell's deposition being only a part of a very voluminous record, there are numerous references to other parts, and, when necessary, these references have been made intelligible by foot-notes.

The Bell patents are so frequently referred to that they have been printed in full at the end of the deposition. They were put in evidence by the Government as a part of its opening case. No other exhibits have been printed in full. They would add greatly to the bulk of the deposition, and would be less easily understood than the foot-notes.

The formal noting of the different recesses, adjournments, etc., has been omitted. The deposition was begun April 4, 1892, and was continued, subject to engagements of Mr. Bell's which necessitated his personal attention. The deposition occupied about six weeks in April and May, one in June, and two in July, and the work was done in Boston, excepting the July part of it when, because of the heat in the city, the hearings were had at a summer hotel in Boston harbor. The original deposition with all the exhibits is filed in the office of the clerk of the United States Circuit Court in Boston.

CHARLES H. SWAN.

DECEMBER, 1908.

Circuit Court of the United States

DISTRICT OF MASSACHUSETTS.

No. 2356A.

IN EQUITY.

UNITED STATES OF AMERICA, COMPLAINANT,

v.

AMERICAN BELL TELEPHONE COMPANY AND ALEXANDER GRAHAM
BELL, DEFENDANTS.

Evidence for Defendants, Taken Pursuant to the 67th Rule of the Supreme
Court of the United States in Equity, as Amended Before Me, Henry L.
Hallett, Special Examiner.

95 MILK STREET, BOSTON, April 4, 1892.

PRESENT: CHARLES S. WHITMAN, Esq., of Counsel for Complainant.

GEORGE L. ROBERTS, Esq., and CHARLES H. SWAN, Esq.,
of Counsel for Defendants.

DEPOSITION OF ALEXANDER GRAHAM BELL.

Direct Examination by GEORGE L. ROBERTS, Esq., *of Counsel for*
Defendants.

Int. 1. Please state your name, age, residence and occupation.

Ans. Alexander Graham Bell; age, forty-five; residence, Wash-
ington, D. C.; I am at present engaged in no regular occupation,
but take an active interest, as I always have done, in the educa-
tion of the deaf.

Int. 2. Are you one of the defendants in the present suit, and
the original grantee named in Patent No. 174,465 of March 7, 1876,
and in Patent No. 186,787 of January 30, 1877?

Ans. I am.

Int. 3. Have you formerly given testimony in relation to your
inventions appertaining to the telegraphic transmission of sounds,
and if so, at what times and places?

Ans. I have. I gave testimony in the *Harmonic Telegraph Interferences* * in Washington, D. C., in the year 1877 on the following days, January 2, 3, 4, 5, 8, 9 and 10; and in Boston, Mass., in the same case, on the 20th of February, 1877. I also gave testimony in the *Dowd* § suit, in the year 1879, in Boston, Mass., on July 8, 9, 10, 11, 12, 14, 21, 23 and 24. In the *Speaking Telephone Interferences* † I gave testimony in Washington in the year 1881, February 26 and 28; my testimony in the *Dowd* § suit was stipulated into this case, and I was cross-examined upon it. I also gave testimony in *The People's Telephone Company's* § case in Washington, D. C., in the year 1883, on the following days, February 20, 21, 22, 23, 24, 26, 27, 28, March 1, 2, 3, 5, 6, 7, 8, 9, 10, 12 and 13; in this case my deposition in the *Dowd* case was stipulated in, and I was cross-examined upon it, and further examined on the re-direct. In addition to my testimony in these cases, I have executed several affidavits in various telephone suits.

Int. 4. Are you a citizen of the United States, and when did you become such?

Ans. I am a naturalized citizen of the United States. I was born in Edinburgh, Scotland. I declared my intention to become a citizen of the United States on the 27th of October, 1874, before the Superior Court of the Commonwealth of Massachusetts, held at Lawrence, Mass., while I was residing at Salem. I was admitted to become a citizen of the United States on the tenth day of November, 1882, before the Supreme Court of the District of Columbia.

Int. 5. What was the character of your early education, and at what schools were you educated?

Ans. I was educated at the Royal High School of Edinburgh, Scotland, and passed through the whole curriculum of that school. I attended lectures on classical subjects, for one year, at the Edinburgh University. I attended a course on anatomy at University

* For the benefit of readers not familiar with Patent Office procedure it may be said that an *Interference* is the proceeding by which the Patent Office settles the question of priority when there is more than one applicant for a patent upon the same invention. For evidence about the *Harmonic Telegraph Interferences* see p. 17, *infra*.

† The *Speaking Telephone Interferences* are described somewhat fully, p. 158, *infra*.

§ Described in the introductory memorandum.

College, London, and I matriculated as an undergraduate of the London University — I think, in the year 1867. From my boyhood I had been specially educated by my father, at home, in subjects relating to sound and the mechanism of speech, as he intended me to follow his own profession and become a teacher of articulation, as he and my grandfather before him had been. I also received, at home, at a very early age, training in music from Signor Auguste Benoit Bertini, and after his death my musical education was carried on, on the Bertini method, by my mother.

Int. 6. What attention did you give to the physical sciences, and particularly to acoustics and electricity, before you came to this country, and where were your studies of this kind carried on?

Ans. From my earliest childhood my attention was specially directed to the subject of acoustics, and specially to the subject of speech, and I was urged by my father to study everything relating to these subjects, as they would have an important bearing upon what was to be my professional work. He also encouraged me to experiment, and offered a prize to his sons for the successful construction of a speaking machine. I made a machine of this kind, as a boy, and was able to make it articulate a few words. Somewhere about the year 1864 or 1865, I accepted the position of teacher of elocution and music in Weston-House Academy, Elgin, Morayshire, and while there I made experiments upon my own mouth to determine the resonance pitches of the mouth cavities during the production of vowel sounds. Considering the instrument of speech as a tube, extending from the vocal cords to the lips, I saw that the constriction of the mouth-passage anywhere divided that tube into two bottle-shaped cavities, placed neck to neck. I came to the conclusion that these cavities, like ordinary bottles, should be capable of producing, by resonance, musical tones, and that the pitch of the tone produced by each cavity should be dependent upon its size, shape, etc. I placed the side of a lead-pencil against my cheek and tapped it forcibly, while I assumed with my mouth the positions for the vowel sounds. The agitation of the air in the front cavity of the mouth produced a hollow sound, like that occasioned by tapping against the side of an empty bottle; and this sound had the element of pitch. I found that the pitch of the front cavity of the mouth

was different for every vowel. Upon then placing the pencil against my throat and tapping it forcibly, as before, I caused an agitation of the air in the back cavity of the mouth; and in this way was able to study the resonance pitches of the back cavity during the assumption of vowel positions. I thus discovered that most vowel positions were capable of yielding a double resonance, the front cavity of the mouth yielding a different tone from that produced by the back cavity. Having familiarized myself with the proper tones of the mouth cavities, I experimented upon myself to ascertain whether I could perceive these tones while I actually uttered vowel sounds. Upon singing all the vowels upon the same pitch of voice, I was delighted to find that I could perceive the characteristic tones of the mouth-cavities as feeble musical effects, mingling faintly with the voice; and I made what I then deemed to be an original discovery, — that vowel quality was produced by the resonance tones of the mouth-cavities mingling faintly with the tone of the voice. I made an elaborate series of experiments to determine the resonance pitches of the mouth-cavities in uttering different vowel sounds, and I communicated the results to the late Mr. Alexander J. Ellis, of London, England. These experiments were made in Elgin, Scotland, somewhere about the year 1864 or 1865. Mr. Ellis informed me that the experiments, which I had thought to be original with myself, had already been made by Helmholtz, and that Helmholtz had demonstrated the compound nature of the vowel sounds by producing them artificially by a synthetical process. For example, he would cause the simultaneous vibration of three tuning-forks of different pitches — one of these would represent the pitch of the voice — and this fork he caused to vibrate in front of a resonator tuned to its own pitch, so as to cause it to produce a loud musical tone. The other two forks corresponded in pitch to the front and back cavities of the mouth in uttering some vowel sound. These forks were caused to resound very faintly. The simultaneous vibration of the three forks produced one loud, fundamental sound, and two higher partial tones. The effect upon the ear was as though someone sang a vowel sound. In an interview with Mr. Ellis, he attempted to describe to me the apparatus used by Helmholtz. Helmholtz kept his forks in vibration by means of electro-magnets and a voltaic bat-

tery; but I found that I had not sufficient electrical knowledge to understand the arrangement used by Helmholtz. I therefore determined to study electricity; for I felt it was my duty, as a student of speech, to study Helmholtz's researches and to repeat his experiments. I do not remember when I first commenced the study of electricity, but I know that during my stay in the city of Bath, in England, I was practically experimenting with ordinary telegraph apparatus, and trying in vain to cause the continuous vibration of a tuning-fork by means of electro-magnets. I think the date of my stay in Bath was 1867, but am not quite sure. Helmholtz's researches were not published in the English language before my arrival in America; and I could not, unfortunately, read his work in the original German; but very shortly before my leaving Great Britain, in 1870, I procured a copy of the French edition of his work.

Int. 7. There was published in London, England, in the year 1875, an English translation by Alexander J. Ellis, of the work of Professor Hermann L. F. Helmholtz, entitled in the original German, "*Die Lehre von den Tonempfindungen als physiologische Grundlage für die Theorie der Musik*," which in the English translation is rendered "On the Sensations of Tone as a Physiological Basis for the Theory of Music." Was that the work of Helmholtz to which you have referred, and was the translator the Mr. Ellis whom you have mentioned?

Ans. Yes.

Int. 8. The French translation of the same work has already been referred to by Professor George F. Barker, a witness in this case, as entitled "*Théorie Physiologique de la Musique*," published at Paris, in 1868. Was that the French translation which you procured just before coming to this country?

Ans. It was.

Int. 9. At what time in the year 1870 did you arrive in this country, and where did you go to reside?

Ans. I arrived in America in August, 1870, and went to reside at Tutelo Heights, near Brantford, in Ontario, Canada.

Int. 10. When, and under what circumstances, did you first come to the United States?

Ans. I was invited by the Board of Education of the city of Boston to make experiments in the city school for deaf-mutes, in order to ascertain whether these children could be taught to speak by means of a system of characters invented by my father, and depicting the actions of the vocal organs in uttering sounds. This system of characters was known as "visible speech." In response to the invitation of the Board of Education, I came to Boston on the first of April, 1871.

Int. 11. When did you begin to reside permanently in the United States, and at what place?

Ans. October 1, 1872. I resided at 35 West Newton Street, Boston, Mass.

Int. 12. Between April 1, 1871, when you first visited Boston, and October 1, 1872, when you came to reside there permanently, how much time did you spend in the United States, and where?

Ans. I remained, I think, about two months in Boston, experimenting at the city school for the deaf and dumb; I also visited the Clark Institution for Deaf Mutes in Northampton, Mass., and the American Asylum for Deaf Mutes in Hartford, Conn. I think I remained about two months at each place. I also resided in Newton Lower Falls, Mass., I think for about two months, where I received some private pupils who were deaf. I do not now recall the exact order of residence in these places, nor the exact dates; my impression is that I lived in Canada, at my father's house near Brantford, a portion of the time during 1871-1872, paying occasional visits to the United States for the purposes I have specified above.

Int. 13. You have mentioned procuring the French translation of Helmholtz's work, previously to your coming to America; what degree of familiarity did you come to have with that work prior to your taking up your residence permanently in Boston?

Ans. I devoted a large portion of my time while in Canada to the study of the work.

Int. 14. In what business were you engaged after coming to reside permanently in Boston, October 1, 1872?

Ans. I was engaged in the work of instructing teachers of the deaf and dumb in the use of my father's system of "visible speech," and in the work of teaching speech to deaf mutes. I opened, at No.

35 West Newton Street, a school of vocal physiology, and received as pupils deaf mutes, teachers of the deaf and dumb, and hearing persons with defective speech. I had become so much interested in the subject of the general education of the deaf and dumb that I also undertook complete charge of the education of a very young deaf child, named George Sanders, who was sent by his parents to live in the same boarding place where I resided. I employed a teacher to carry on his general education under my own direction.

Int. 15. For the better understanding of your testimony which is to follow, will you please state your successive places of residence, and the locations where you carried on your professional occupation, down to the time when you relinquished that occupation?

Ans. In October, 1872, I resided at 35 West Newton Street, Boston, Mass., where I also carried on my professional work. In October, 1873, I resided in Salem, Mass., in the house of Mrs. George T. Sanders, grandmother of my little pupil, and I carried on my professional work at No. 18 Beacon Street, Boston, in rooms connected with the Boston University. My place of residence remained at Salem until, I think, January, 1876, when I removed to rooms No. 5 Exeter Place, Boston; my professional work being carried on, as before, at No. 18 Beacon Street. I resided at Exeter Place until my marriage, July 11, 1877. On or about the fourth day of August, 1877, I sailed for Europe, and remained abroad until November 10, 1878. During these years preceding my marriage it was my custom to spend my summer vacation — from about the middle of July to the end of September — with my parents in Brantford, Ont., and I also usually spent the Christmas week with them, returning to my professional duties at the beginning of the new year. I always considered my professional year as commencing on the first of October, and ending in the early part of July. I aimed to spend my summer vacation with my parents in Brantford, but the length of my stay there was not always uniform.

Int. 16. In your Letters Patent No. 174,465 of March 7, 1876, mention is made of a pending application filed in the United States Patent Office February 25, 1875, — I show you a certified copy of the petition, specification, oath and drawings as originally filed February 25, 1875, in the matter of the application of Alexander

Graham Bell for a patent for Improvement in Transmitting Telegraphic Messages — is this the application so referred to?

Ans. It is.

[*Counsel for defendants puts in evidence the certified copy just mentioned, and it is marked "Defendants' Exhibit Bell's Application of February 25, 1875, H. L. H., Special Examiner."*]

Int. 17. In your Letters Patent No. 186,787 of January 30, 1877, reference is made to another application pending in the United States Patent Office, wherein is described a method of and apparatus for inducing an intermittent current of electricity upon a line wire, whereby musical tones can be produced, and a number of telegraphic signals be sent simultaneously over the same circuit, in either or in both directions, — I show you a certified copy of the petition, specification, oath and drawings as originally filed, March 10, 1875, in the matter of the application of Alexander Graham Bell, for a patent for Improvement in Transmitting and Receiving Telegraphic Signals or Messages, — is this the application so referred to?

Ans. It is.

[*Counsel for defendants puts in evidence the certified copy last mentioned, and it is marked "Defendants' Exhibit Bell's Application of March 10, 1875, H. L. H., Special Examiner."*]

Int. 18. When did your experiments begin in this country which culminated in these applications, and in still another application filed March 6, 1875, which resulted in the issue of Patent No. 161,739,* dated April 6, 1875, and which has already been put in evidence by the complainant.

Ans. In October, 1872, when I came to this country to reside permanently, but the inventions themselves had originated before.

Int. 19. Briefly stated, what incited you to begin experimenting upon harmonic multiple telegraphy, and what was the character of the earlier form of apparatus used in this country?

Ans. My knowledge of Helmholtz's apparatus for the artificial production of vowel sounds incited me to experiments of a similar character, and gave rise in my mind to the inventions referred to.

The earlier form of apparatus, constructed in October, 1872, consisted of tuning-forks arranged substantially after the manner

* For multiple-telegraph instruments.

described by Helmholtz. Each transmitting instrument consisted of a tuning-fork, the prongs of which were placed between the poles of an electro-magnet. The tuning-fork itself was horizontal, and a wire connected with one of the prongs completed a voltaic circuit by dipping into mercury. Upon causing the tuning-fork to vibrate, the wire attached to the prong was alternately lifted out of the mercury and depressed into it again. The circuit of which the fork formed a part was thus made and broken at every vibration of the fork. The poles of the electro-magnet attracted the prongs of the tuning-fork at each make of the circuit, and released them when the circuit was broken. The intermittent attraction of the electro-magnet thus caused the transmitting fork to remain in continuous vibration, emitting continuously its musical tone. By the depression of a telegraph key, the current rendered intermittent by the vibration of the transmitting fork was directed to a line wire which passed to a receiving instrument consisting of an electro-magnet between the poles of which appeared the prongs of a tuning-fork. Every time the prong of the transmitting fork made contact with the mercury below it, the prongs of the receiving fork were attracted by the poles of the electro-magnet, between which they were placed; and every time the prong of the transmitting fork broke contact with the mercury below, the prongs of the receiving fork were no longer attracted by the electro-magnet, but allowed to move freely in the manner of a tuning-fork left to itself. Thus, at every vibration of the transmitting fork, the prongs of the receiving fork were attracted by the receiving electro-magnet and released. When the receiving fork had normally the same pitch as the transmitting fork, the intermittent attraction of the electro-magnet would cause it to be thrown into vigorous vibration, thus producing a musical sound of similar pitch to that occasioned by the vibration of the transmitting fork. When the pulls of the electro-magnet were properly timed to the normal movement of the fork, it was set into vigorous vibration, just as a swing can be caused to oscillate with great amplitude by gentle pushes from the hand, when properly timed to the movements of the swing. If we push the swing at the wrong time — that is, when its normal movement is towards instead of from the hand — each push retards the movement of the swing, and a series of ill-timed shoves would

bring it to rest. In a similar manner, ill-timed pulls from the electro-magnet of the receiving instrument would interfere with the free vibration of the receiving tuning-fork. Thus, if the pitch of the sound normally produced by the receiving fork was different from that normally produced by the vibration of the transmitting fork, so that the two were not in unison, then a series of electrical impulses sent from the transmitting to the receiving instrument would not cause violent vibration in the receiving fork.

Int. 20. How did the apparatus which you had in mind differ from the vowel-producing apparatus of Helmholtz, and what was your aim as distinguished from his?

Ans. Helmholtz used a single transmitting fork, which was so arranged as to cause the simultaneous vibration of a number of receiving forks of different pitches, but all producing sounds that were harmonics of the transmitting fork. I proposed to use a number of transmitting forks of different pitches, and a number of receiving forks, each tuned to the pitch of one of the transmitting forks; and I aimed so to arrange the pitches of these instruments that no transmitting fork should be able to cause vigorous vibration in the prongs of a receiving fork of different pitch from its own. Each transmitting fork was to be provided with a key, by the depression of which electrical impulses from the fork could be sent on to a line wire extending to some distant place where the receivers were to be located. The depression of any key would thus cause on the line wire intermittent impulses of electricity, which would succeed one another with the frequency of a musical sound; with the frequency, in fact, of the vibration of the transmitting fork connected with that key. This intermittent current, passing through all of the coils of all of the electro-magnets of all of the receiving instruments, would occasion the forcible vibration of that fork alone which was the unison of the transmitting fork employed. That is, the receiving fork having the pitch of the transmitter employed would continuously emit its fundamental tone all the time the key at the other end was depressed, but the moment the key at the transmitting end was raised, the receiving fork would stop. Thus, if the key connected to any one of the transmitters should be operated in the manner of an ordinary Morse key, long and short musical signals, correspond-

ing to dots and dashes, would be emitted by that receiving fork which had the same pitch as the transmitter employed, but the other receivers would not be thrown into vigorous vibration. Thus, the manipulation of any key would cause the vigorous vibration of one, and one only, of the receiving instruments, so that a Morse message transmitted by the manipulation of one of the keys would be received by one, and one only, of the receivers. If two or more of the keys should be depressed simultaneously, then the two or more receiving forks corresponding in pitch to the transmitting forks employed would be set into vigorous vibration; each fork responding to the signal sent from one, and one only, of the transmitters. Thus, upon my method, two or more telegraphic messages could be sent simultaneously along a single line wire, and received separately upon distinct receiving instruments.

Int. 21. The transmitting and receiving instruments shown in your application of February 25, 1875, are provided with vibrating armatures, which consist of single flat plates, instead of tuning-forks, — when did you make this change in your harmonic telegraph apparatus?

Ans. In the fall of 1873. I think about November.

Int. 22. What form of receiving instrument did you most frequently use in your experiments between November, 1873, and February, 1875?

Ans. During the winter of 1873–74 the form of receiving instrument which I usually employed consisted of a flat plate or blade of steel which was clamped at one end to the top of a post or standard extending up from the baseboard. The blade was thus caused to extend horizontally over the poles of a double-pole electro-magnet, mounted vertically on the same base. A subsequent modification of this is shown in Fig. 3 of my application, filed February 25, 1875, in which the steel reed is provided with a tuning apparatus, and a single-pole electro-magnet is used, provided with an adjusting device whereby its distance from the free end of the steel reed can be properly regulated.

Int. 23. Did you ever, during the period mentioned in the last preceding interrogatory, hear from such a receiver any tone other than that due to the normal vibration of its free reed, and if so, under what circumstances did you first have that experience?

Ans. Yes; while in Salem, during the winter of 1873-74, I had arranged two transmitting instruments of different pitch, which I shall term T and T', provided with keys, K and K', on the same circuit with two receivers, R and R'. One of these receivers, say R, was properly tuned to its corresponding transmitter T, but I was unable, with the means at my command, to tune the receiver R' to the same pitch with the transmitter T'; thus, upon depressing the key K the receiver R was thrown into vigorous vibration, but the receiver R' did not respond excepting by a slight trembling that was perceptible to the sense of touch. Upon depressing key K', neither of the receivers R and R' responded vigorously, and upon depressing K and K' simultaneously, the receiver R responded vigorously, but R' did not. The steel plate or reed of R', however, could be felt to tremble when touched by the hand, and the thought occurred to me to place my ear against the trembling reed. I did so, and perceived two musical tones, corresponding in pitch to the two transmitters employed, but different in pitch from the sound produced when the reed of the receiver at my ear was plucked with the finger.

Int. 24. Was this discovery, that the reed of such a receiver could be forced to give out a sound of different pitch from that of the tone produced by its normally free vibration, subsequently made use of by you for any purpose of experimentation?

Ans. Yes; it was constantly my habit to ascertain how to tune the reeds of my receivers by pressing the reed firmly against my ear while the transmitter was in operation, and noticing the pitch of the forced vibrations produced; and I would then pluck the reed with my finger, and notice the pitch of the sound produced by its free vibration. If the sound produced by the reed when damped was higher in pitch than the normal tone of the reed, I then shortened the free portion of the reed; if it was lower, I lengthened it.

Int. 25. You have mentioned the fact of your testifying in the *Harmonic Telegraph Interferences* in January and February, 1877, — were your two applications of February 25, 1875, and March 10, 1875, and your Patent No. 161,739 of April 6, 1875, involved in those interferences?

Ans. They were.

Int. 26. I have here a certified copy of the preliminary statement of Alexander Graham Bell, filed in the United States Patent Office May 17, 1876, in the matter of the interference between Alexander Graham Bell, and Paul LaCour, and Elisha Gray, relating to the subject-matter of harmonic multiple telegraphy. It is dated Boston University, April 27, 1876, and the oath thereto is dated May 15, 1876, — did you sign and make oath to the original of this preliminary statement, as appears in the certified copy thereof?

Ans. I did.

Int. 27. In view of the fact that this preliminary statement was prepared long before any controversy had arisen in relation to the electric speaking telephone, and that the matters contained therein constitute a proper introduction to the main subject upon which you are now called to testify, I will ask you whether the several statements made in that preliminary statement, relating to the history of your inventions mentioned therein, are correct, and whether you adopt them as part of your present testimony.

Ans. I believe they are correct, and I adopt them as part of my present testimony.

[*Counsel for defendants puts in evidence the certified copy, just mentioned, and it is marked "Defendants' Exhibit Bell's Preliminary Statement in Harmonic Telegraph Interferences, H. L. H., Special Examiner."*]

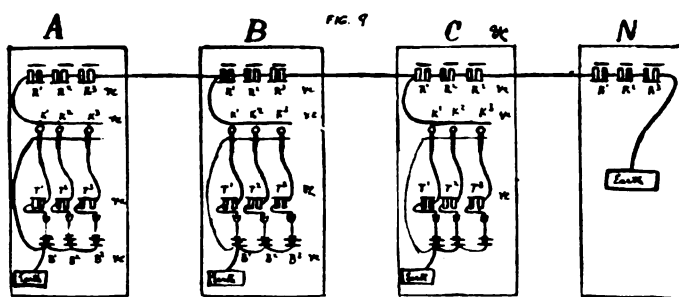
Int. 28. In your application of March 10, 1875, you provided for the use of induction coils between the circuit-breaking transmitters and the tuned-reed receivers, and you stated therein :

"To effect the transmission along the line wire of a succession of secondary or induced electrical impulses, I find it to be necessary that the successive and alternate makes and breaks of the primary circuit should be of equal and uniform duration."

And for this purpose you described a rotating circuit-breaking cylinder which caused the successive intervals, at which the current was alternately put on and taken off the line, to be equal in duration, while the rotation was rapid enough to create a succession of intermittences of current, at a rate corresponding to the number of vibrations executed by the free reed of the receiver in producing its normal musical tone. Was this your original plan, and, if not, how did you arrive at it?

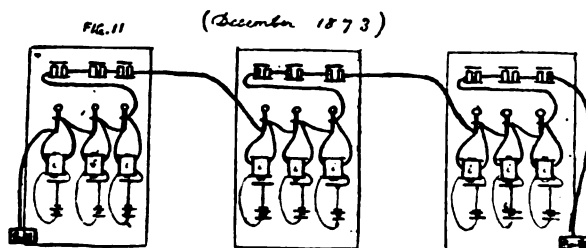
Ans. It was not my original method. I arrived at it from the consideration of certain difficulties that presented themselves to my mind in the operation of instruments making and breaking the main circuit upon which the receivers were placed. The nature of these difficulties will be understood by consulting the electrical diagrams shown in my preliminary statement in the *Harmonic Telegraph Interferences*. In the winter of 1873-74 one arrangement of circuit at which I had arrived is shown in Fig. 9,* which represents four telegraphic stations, A, B, C and N. It will be observed that there is free earth communication only at one end of the circuit N, so that signals could only be transmitted along the circuit in the direction A, B, C, etc., N. A method of obviating the difficulty occurred to me about December, 1873, and is illustrated in Fig. 11 † of my preliminary statement. Instead of causing the interrupters to make and break the main line, they make and break only the primary circuit of an induction coil; and the secondary circuit, by the depression of a key, can be placed in circuit with the main line. This

*



(NOV. 1873.)

†



i. i. v. Induction Coils

plan admitted of free earth communication at either end of the circuit, and thus allowed of communication in either or in both directions. Figs. 12, 13 and 14 illustrate various methods of using an induction coil. While the use of an induction coil enabled me to secure communication in both directions upon the main circuit, it introduced another difficulty that had not hitherto presented itself. When the primary circuit of an induction coil is made, a momentary impulse of electricity appears in the secondary circuit, but no further effect is produced, so long as the primary circuit remains unbroken and the electrical current traversing it unchanged in strength. When, however, the primary circuit is broken, again a momentary impulse of electricity appears in the secondary circuit. Thus there are twice as many electrical impulses in the secondary as in the primary circuit, and thus an ordinary electro-magnet placed in the secondary circuit would attract its reed armature twice as many times per second as it would do had it been placed in the primary circuit. I feared that, under these circumstances, the transmitting reed would be unable to cause the vibration of a receiving reed of its own pitch, but that the pitch of the receiver would have to be an octave above the pitch of the transmitter. Upon considering this subject more closely, however, I recognized the fact that the alternate impulses in the secondary circuit were of opposite kind. For example, when the primary circuit is made, suppose that a positive impulse of electricity should momentarily appear in the secondary circuit, then, when the primary circuit is broken, the secondary impulse will be negative.

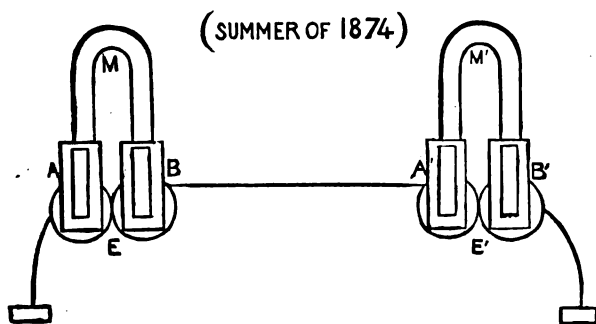
Thus the vibration of any of the transmitting reeds would cause a reversed intermittent current in the secondary circuit; that is, a succession of alternately positive and negative impulses. In considering the action of such impulses upon the receiving reeds, I saw that the polarity of the electro-magnets of the receiving instruments would be reversed at every impulse, and it occurred to me that if the reed armature of the receiving instrument should be made permanently magnetic, it would be alternately attracted and repelled by the electro-magnet. For example, when the transmitting reed makes contact in the primary circuit of the induction coil, suppose that the secondary impulse momentarily produced should cause the electro-

magnet of a receiving instrument to attract its polarized reed, then when the transmitting reed breaks the primary circuit, the momentary impulse appearing in the secondary circuit will be of opposite kind to the first; the polarity of the electro-magnet of the receiver will thereby be reversed, and the polarized reed armature should be repelled. Under such circumstances, the pitch of the receiving reed should be the same as the pitch of the transmitting reed, although the number of impulses in the secondary circuit is twice the number in the primary circuit. In order to render the reeds of the receiving instrument permanently magnetized, I proposed to attach them to the poles of a permanent magnet, and allow the free ends of the reeds to be attracted and repelled by the poles of an electro-magnet.. In considering the action of the apparatus, however, a difficulty made its appearance. Unless the attractive and repulsive impulses of the electro-magnet were properly timed to the normal vibrations of the armature reed of the receiving instrument, they would tend to retard the motion of the reed. For example, suppose an attractive impulse from the electro-magnet tends to pull the reed towards its pole. The reed starts moving towards its pole. Now if the repulsive impulse from the electro-magnet should come before the reed has commenced to swing back upon its path, the repulsive impulse will tend to check the movement of the reed, instead of accelerating its motion. In order that the receiving reed should be thrown into full and vigorous vibration, it appeared to be necessary that the attractive and repulsive impulses should come at equal distances apart, so that the reed of the receiver should be attracted only while it was normally moving towards the electro-magnet, and repelled only when it was normally moving away. In considering the action of the transmitting reeds in making and breaking the primary circuit, it was evident that the alternate positive and negative impulses induced in the secondary circuit would not come at equal distances apart unless the primary circuit should be closed for exactly the same length of time it remained open. That is, the duration of the makes of the primary circuit should be equal to the duration of the breaks. I felt it to be extremely problematical whether any of the circuit-breaking reeds of the transmitting instruments could fulfil this condition, and I began to consider what change

in the transmitting instruments could be made that would enable them to do it. It then occurred to me that the permanently-magnetized reed of a receiving instrument should, if caused to vibrate by mechanical means, itself occasion electrical impulses in the coils of its electro-magnet of the kind required. For I was aware of the fact that when a permanent magnet is moved towards the pole of an electro-magnet, a current of electricity appears in the coil of the electro-magnet; and that when the permanent magnet is moved from the electro-magnet, a current of opposite kind is induced in the coils. I had no doubt, therefore, that a permanent magnet, like the reed of one of my receiving instruments, vibrating with the frequency of a musical sound in front of the pole of an electro magnet, should induce in the coils of the latter alternately positive and negative impulses corresponding in frequency to the vibrations of the reed, and that these reversed impulses would come at equal distances apart.

The mode of operating the receiving instruments as transmitters that occurred to my mind, in pursuance of this idea, is shown in Fig. 15 of my preliminary statement in the *Harmonic Telegraph Interferences*. M and M' are two permanent horseshoe magnets in

Fig. 15.
BELL'S PRELIMINARY STATEMENT,
HARMONIC TELEGRAPH INTERFERENCES.



two different places, and A, B, A', B'. are steel reeds attached to the poles of the permanent magnets and arranged in beds, after the manner of free reeds in parlor organs, so as to be capable of being set in vibration by wind. The reeds A and A' are of similar pitch, and the reeds B and B' also have the same pitch; but A and B are

of different pitches; so with A', B'. The free ends of the reeds projected above the poles of electro-magnets E, E'. The instruments are arranged to operate either as transmitters or receivers. For example, let the reed A be set in vibration by wind. As it moves to and fro in front of one of the poles of the electro-magnet E it causes alternately positive and negative impulses to appear upon the circuit, and these impulses are at equal distances apart, for the current is of one kind when the reed A moves towards the pole of the electro-magnet, and reverses only when the reed moves from the electro-magnet. The reversed impulses cause the electro-magnetic poles presented to the other reeds B, A', B' alternately to attract and repel the reeds. The reed A' having normally the same pitch as the transmitting reed A is thrown into vigorous vibration. But the reeds B and B' having normally a different rate of vibration from the reed A, are attracted and repelled at the wrong times, so that they are not thrown into forcible vibration. In this arrangement voltaic batteries, current-interrupters, and induction coils became unnecessary, and I was fascinated with the simplicity of the arrangement of circuit. In considering the operation of the instruments, however, certain difficulties made their appearance. It seemed extremely doubtful whether a magneto-electric current generated by the vibration of a magnetized reed in front of an electro-magnet would be sufficiently powerful to produce, at the receiving end of the circuit, a vibration sufficiently intense to be utilized practically, on real lines, for purposes of multiple telegraphy. The arrangement seemed to fulfil perfectly the condition I desired, namely, a succession of alternately positive and negative impulses which should be equally distant apart. But I was so impressed with the idea that the magneto currents generated in the way proposed would be too feeble to be utilized on actual working lines, that I sought for some more powerful means of producing reversed impulses of this kind, and I hit upon the plan shown in my application of March 10, 1875, of making and breaking the primary circuit of an induction coil by means of a rotating cylinder, as shown in Fig. 1 of that specification. The surface of the cylinder consisted of alternately conducting and non-conducting surfaces, so that when the cylinder was rotated, a contact finger, pressed against

the cylinder, would make and break the primary circuit accordingly as it made contact with a conducting or non-conducting surface. As the conducting and non-conducting surfaces were of equal length, the duration of the make of the primary circuit was equal to the duration of the break, and thus the alternately positive and negative impulses induced in the secondary circuit were at equal distances apart, and were, therefore, competent to cause the forcible vibration of the receiving reeds if the cylinder was rotated at such a speed as to cause the electrical impulses to succeed one another with the frequency of a musical sound of the pitch of one of the reeds. Under such circumstances, the reed would be alternately attracted and repelled by its electro-magnet and be thrown into powerful vibration, thereby emitting its musical note. In my specification of March 10, 1875, I show a form of receiving instrument to be operated by means of a rotating cylinder, in which the steel reeds are magnetized by contact with the poles of a permanent magnet, and the free ends are vibrated between the poles of electro-magnets, arranged as shown in Fig. 2.

Int. 29. You have referred to your familiarity with Helmholtz's demonstrations and discoveries as described in his work on "Sensations of Tone," at the time when you set out with your experiments relating to harmonic multiple telegraphy. Did you, before the period when your applications of February 25, March 6, and March 10, 1875, were prepared and filed, become familiar with any other experimental demonstrations relating to the character of sound vibrations and the graphical representation of the same?

Ans. Yes. I became familiar with two very remarkable scientific instruments illustrating the character of sound vibrations and the graphical representation of the same. I allude to the manometric capsule of Koenig and the phonautograph of Léon Scott.

Int. 30. In what connection and for what purpose did you become interested in these two instruments, and when was it?

Ans. I became familiar with these instruments in the winter of 1873-74, and it occurred to me that they could be utilized in my professional work, which at that time largely related to the teaching of speech to children who were deaf. These instruments reproduced to the eye those details of sound vibration that produce in our ears

the sensation we term *timbre* or quality of sound. I thought that if deaf children could see speech as we hear it, they might themselves be taught more easily to articulate. In order that I may make my meaning clear, allow me to describe the construction of the manometric capsule. The essential feature of the apparatus consists of a cavity which is divided into two parts by means of a stretched membrane. A speaking-tube communicates with the chamber on one side of the diaphragm, and a gas pipe with the chamber on the other. Leading from this chamber is a gas burner with a fine vertical orifice. A current of gas is turned on and lighted at the burner. The result is a fine jet of flame, forming a sort of pencil of light. When, now, a sound is uttered into the mouth-piece of the speaking tube, the air vibrations are transmitted, through the agency of the membrane, to the gas in the chamber beyond, and the gas flame is thereby caused to vibrate up and down. When an air condensation reaches the membrane, compression of the gas results, the velocity of outflow is increased, and the flame becomes taller; and conversely, a rarefaction causes the flame to become shorter. The length of the flame is dependent upon the pressure of the confined gas, so that the flame varies in length as the gas varies in pressure. When a sound is uttered into the mouth-piece of the speaking-tube, the flame vibrates up and down with great rapidity, and the variations in the length of the flame correspond to the variations in the density of the air during the production of the sound. The flame, however, vibrates with such rapidity that the eye cannot follow its movements. In order to enable the eye to study the character of the changes that take place in the height of the flame, a mirror is employed, and we view the reflection of the flame instead of the flame itself. For convenience, four mirrors are employed. These are arranged on the vertical sides of a cubical support capable of rotating about a vertical axis. When the mirror-support is caused to revolve with great rapidity, the reflection of the stationary flame appears like a long band or ribbon of blue light. But when we speak to the apparatus, an undulatory band of light makes its appearance in the mirror. The upper edge of the luminous band appears to be carved into beautiful waves of various shapes and sizes, and when we sing different vowel sounds into the mouth-piece of the instrument, retaining the voice on

a uniform level, the form or shape of the undulations visible in the mirror changes with every vowel. I thought that if I could discover the shape or form of vibration that was characteristic of the elements of English speech, I could depict these upon paper by photographic or other means for the information of my deaf pupils.

Suppose, for example, that I could present to a pupil a photograph of the undulations produced by uttering into the instrument the vowel *e e*. I could then get the deaf child to make sounds into the mouthpiece of the manometric capsule, and observe the forms of the flame-undulations thereby produced. He could experiment in this way until he could produce an undulation of similar form to that shown in the photograph. He would then know that he was sounding the vowel *e e*. I believed that the instrument might become of great value in teaching articulation to the deaf, and I therefore made a careful study of the apparatus and its mode of operation.

In using the manometric capsule of Koenig I found that the wind occasioned by the rotation of the mirror-support was a source of great inconvenience, as the flame would be blown to one side instead of remaining vertical, and the form of the vibrations produced by the voice would thus often become distorted. I remedied this largely by the insertion of a plane sheet of glass between the revolving mirror-stand and the flame. I also found that the flame was most sensitive to sound vibrations when it was lowered to such an extent that the whole of the flame was blue. Under such circumstances, very beautiful and characteristically-shaped undulations appeared in the mirror when a person spoke softly into the mouthpiece of the instrument. The appearance, however, was so faint that I saw it was hopeless to attempt to photograph the appearance, for the information of my deaf pupils, and I therefore sought to utilize the other form of apparatus to which attention has been directed. I allude to the phonautograph of Léon Scott. At the time I saw this instrument, in the Institute of Technology, an improvement had just been made upon it by Morey. The phonautograph consisted essentially of a stretched membrane, in front of which was arranged a conical mouth-piece, into which a person could speak. A long and light lever of wood was hinged to one edge of the membrane-support, and the other end projected horizontally beyond the opposite edge, and

carried at its extremity a vertical bristle. The centre of the membrane was attached to this lever so that vibration of the membrane would necessarily cause vibration of the lever and of the bristle at the extremity of the lever. The lower end of the bristle just touched the surface of a plane sheet of glass covered with lampblack. Mechanism was provided whereby the plate could be moved horizontally along in a direction at right angles to the direction of vibration of the bristle. The operation of the instrument was as follows :

A person uttered a sound into the cone of the phonautograph, thereby causing the vibration of the membrane and its attached lever, and the bristle at the end of the lever was forced to partake of the motion. While the sound was being uttered the sheet of smoked glass was caused to move horizontally under the vibrating bristle, at a uniform rate of speed. The point of the bristle thus traced a sinuous line upon the lampblack surface below. It scraped off the lampblack wherever it touched. The undulatory curve produced formed a graphical representation of the vibration of the bristle, and hence of the lever and of the membrane. As the membrane and attached lever were caused to vibrate by the action of air-vibrations produced by the voice, it appeared to me that the curve traced upon the smoked glass should also represent graphically the changes of density occurring in the air during the production of the sound, and hence should correspond in form to the flame-undulations of the manometric capsule under the influence of a similar sound. The flame, as I have already said, gave forth too feeble a light to be photographed by any means at my command, but it seemed to me that in the phonautograph I had an instrument by means of which the forms of vibration characteristic of the English elements of speech could be written down automatically by the voice itself, in such a manner that deaf children could see them. I proposed to use these glass plates as negatives, and, by photographic means, print off copies of the tracings for the use of my pupils. I proposed to place one of these photographs in the hands of a deaf child, and then direct him to make sounds into the mouth-piece of the manometric capsule until he could produce flame-vibrations of similar shape to those on the photograph. I presumed that he would then be pronouncing a

similar sound to that which had been uttered into the cone of the phonautograph when the tracing was originally made.

I made a number of experiments with the phonautograph at the Institute of Technology, to ascertain how far it was practicable to use the instrument in the manner I desired. I sang all the vowel sounds, with the voice at a uniform pitch, and observed that each vowel seemed to yield a tracing of characteristic form different from the others. I then sang the same vowels, in the same way, into the mouth-piece of the manometric capsule, and compared the tracings of the phonautograph with the flame-undulations visible in the mirror. The shapes of the vibrations obtained in the two ways were not exactly identical, and I came to the conclusion that the phonautograph would require considerable modification to be adapted to my purpose. The membrane was loaded by being attached to a long lever, and the bristle, too, at the end of the lever, seemed to have a definite rate of vibration of its own. These facts led me to imagine that the true form of vibration characteristic of the sounds of speech had been distorted in the phonautograph by the instrumentalities employed. I therefore made many experiments to improve the construction of the instrument. I constructed, at home, quite a number of different forms of phonautographs, using membranes of different diameters and thicknesses, and of different materials, and changing the shape of the attached lever and bristle.

The experiments with the phonautograph, to which I have referred, were made, I think, in the spring or early summer of 1874. I know that I was carrying on experiments of this kind before and after the thirteenth day of June, 1874.

Int. 31. You mention June 13, 1874, as having a definite relation to your experiments with phonautographic apparatus; will you state how you are enabled to fix this date?

Ans. Because I remember I was so much interested in the possible utilization of the manometric capsule and phonautograph in the work of teaching speech to the deaf, that while in the midst of experiments upon the phonautograph, I gave a public address upon the subject, before the Second Convention of Articulation Teachers of the Deaf and Dumb, which met in Worcester, Mass., on Saturday, the thirteenth day of June, 1874. The proceedings of this conven-

tion were published in the "American Annals of the Deaf and Dumb," in October, 1874, Vol. XIX., No. 4, pp. 217, 218 and 219, from which I read the following :

"Professor A. Graham Bell, of the Boston University, was elected president. . . .

The president gave a description of a new method of investigating the mechanism of speech, invented by Mr. Oakley Coles, of England. He also exhibited some apparatus, lent by the Massachusetts Institute of Technology, intended to render the vibrations of sound visible, and to enable the human voice to record its own vibrations upon glass. These instruments were invented by Scott and Koenig, of Paris, and it is thought that they may prove of assistance to articulation-teachers of the deaf and dumb. They are founded upon the mechanism of the ear.

'The manometric capsule' consists of a cavity in a piece of wood, divided into two portions by a partition of gold-beater's skin. One compartment connects with a gas-pipe, so that it can be filled with gas, which is lighted at a burner let into one side of the capsule. The other compartment is connected with a speaking tube. Whenever a noise is made in the tube, the vibrations of the air are communicated through the membrane to the gas, and thence to the flame. The flame moves up and down just as many hundred times per second as the voice vibrates. On looking at the reflection of the flame in a mirror, which is kept rapidly revolving, the most beautiful appearances present themselves: Every different sound that is uttered in the tube causes the flame to assume a new aspect in the mirror. The vowel *ē* presents the appearance of a long band of light, with teeth like a saw. When the vowel *ī* (in *it*) is sounded, each tooth of the saw becomes notched. The vowel *ē* (in *bed*) causes a most lovely and complicated pattern to appear, like a piece of Brussels lace made of blue flame. In fact, every sound has its own distinct image in the mirror. It was suggested that if teachers would note the forms resulting from the English elements, deaf mutes, by uttering sounds into the tube and observing their appearance in the mirror, could tell at once whether they were giving the correct sounds.

The other instrument, 'the phonautograph' (as improved by Mr. Morey, of the Massachusetts Institute of Technology), consists of a speaking-trumpet, closed at one end by a stretched membrane, to which is attached a light lever of wood. The membrane vibrates when a sound is made, and communicates the vibration to the wooden style. The long arm of the lever is caused to scratch a line upon a piece of smoked glass. It is found that each different sound is represented by a particular curved line upon the glass. Glasses were exhibited showing the lines resulting from the English elements."

Int. 32. Before leaving the subject of the phonautograph, will you state briefly what form it finally took under your hands, and when?

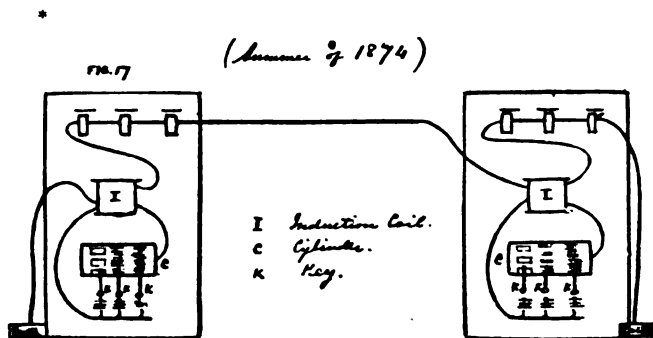
Ans. I was struck by the likeness between the mechanism of the phonautograph and the mechanism of the human ear, the membrane of the one being loaded by a lever of wood, and the membrane of the other by levers of bone. It appeared to me that a phonautograph modeled after the pattern of the human ear would probably produce more accurate tracings of speech-vibrations than the imperfect instrument with which I was operating. I thought, therefore, it would be well to obtain precise information concerning the shape of the membrane of the human ear, the shapes of the bones attached to it, the mode of connection between the two, etc. For this purpose, I consulted a distinguished aurist — Dr. Clarence J. Blake, of Boston. He seemed to be much interested in my experiments, and suggested that, instead of trying to make a phonautograph modeled after the pattern of the human ear, I should attempt to use a human ear itself, taken from a dead subject, as a phonautograph. He offered to make an anatomical preparation for the purpose. He did so, very shortly before my departure for Canada on my summer vacation in 1874. The specimen consisted of a portion of a human ear, containing the membrane of the tympanum with two bones attached (the *malleus* and *incus*). The other bone (the *stapes*) had been removed, and I substituted for it a style of hay attached to the *incus*. I moistened the membrane with glycerine and water, and arranged a sort of speaking-tube to take the place of the outer ear. When a person sang or spoke to this ear I was delighted to observe a vibration of all the parts, and the style of hay vibrated with such amplitude as to enable me to obtain tracings of the vibrations upon smoked glass. I made a few experiments with the apparatus in Salem, Mass., just before leaving for Canada, in July, 1874, and I then carried the instrument up to Canada with me, where I continued making experiments with it during that summer vacation, at the home of my parents near Brantford.

Int. 33. Recurring now to the magneto-electric apparatus, which you have described in connection with Fig. 15 of the drawings, forming part of your preliminary statement in the *Harmonic Telegraph*

Interferences, will you state when you devised that apparatus, and compare the character of the electric currents produced thereby with those produced by the rotating circuit-interrupter operating through an induction coil, as described in your application of March 10, 1875?

Ans. The apparatus shown in Fig. 15 of my preliminary statement in the *Harmonic Telegraph Interferences* was devised in the summer of 1874. I shall compare the operation of that apparatus with the operation of the circuit-breaking cylinder shown in Fig. 17 * of my preliminary statement in the *Harmonic Telegraph Interferences*, which refers to the same apparatus shown in the application of March 10, 1875, Fig. 1 and Fig. 4.

I have already stated that both forms of apparatus shown in Fig. 15 and Fig. 17, when transmitting a musical tone, produced upon the line wire a succession of alternately positive and negative impulses of electricity, succeeding one another with the frequency of a musical sound, and coming at equal intervals of time apart. In this respect the operation of the two forms of apparatus was alike. There were, however, radical differences in relation to the character of the electrical impulses produced, to which I gave careful and serious attention. The circuit-breaking apparatus shown in Fig. 17 produced a momentary impulse in the secondary circuit at the moment when the primary circuit was made, and again at the moment when it was broken. But during the interval between these points of time, no electrical effect at all appeared upon the secondary circuit. During the continuance of the make, the strength of the current in the primary circuit was uniform, and, therefore, no secondary impulse



was generated excepting at the moment of commencing. So, again, during the continuance of the break of the primary circuit, no electrical current traversed the primary wires of the coil, and consequently no electrical effect was produced upon the secondary circuit excepting at the moment when the primary circuit was broken. Thus the circuit-breaking apparatus produced upon the secondary circuit a reversed intermittent current, characterized by the alternate presence and absence of electricity upon the circuit; the electrical impulses consisting of sudden, instantaneous effects of uniform intensity, alternatively positive and negative in character; and, during the interval between these impulses, no electrical effect appeared upon the line wire. On the other hand, an electrical effect *did* appear upon the line wire between the impulses of positive and negative electricity in the operation of the apparatus shown in Fig. 15, and the impulses themselves were not sudden and instantaneous and of uniform intensity, but consisted of gradual and continuous changes of intensity, corresponding to the changes in the velocity of movement of the inducing reed. This will be obvious by considering the mode of operation of the instruments shown in Fig. 15. In these instruments, the steel reeds A, B, A', B' are in magnetical contact with the poles of the permanent magnets M and M', and are so arranged that they can be thrown into vibration, either mechanically, by a current of wind, or magnetically, by the varying attraction or repulsion of the electro-magnets in front of which they are placed. Now consider the nature of the electrical effect produced when one of the reeds — say A — is thrown into vibration by the action of a current of wind. To all intents and purposes, the reed, by virtue of its contact with the pole of the magnet, becomes itself a permanent magnet. Now when a permanent magnet is moved towards the pole of an electro-magnet, not only is a current of electricity thereby induced in the coils of the electro-magnet, but the strength and intensity of the electrical effect produced is dependent upon the velocity of the movement of the permanent magnet. The more rapidly it is moved toward the pole of the electro-magnet, the greater is the strength of the electrical current induced by its motion. And so when the permanent magnet moves from the electro-magnet. In this case the electrical effect is of

opposite kind to that produced by the approach. That is, if positive electricity be produced by the approach of the permanent magnet, negative electricity will be induced by its recession, and *vice versa*. And the strength of the current induced by moving the permanent magnet away from the pole of the electro-magnet will be dependent upon the velocity with which the permanent magnet recedes. Now when the reed A is thrown mechanically into vibration, the velocity of its motion is different in different parts of its path. The strength or intensity of the electrical effects induced in the coil of the electro-magnet E must, therefore, necessarily also vary from moment to moment; the intensity at each moment being dependent upon the velocity of movement of the reed at that particular time.

Int. 34. You have stated that you gave careful and serious attention to the character of the electrical effects produced by the magneto-electric apparatus represented by Fig. 15 of the drawings belonging to your preliminary statement in the *Harmonic Telegraph Interferences*. Did such attention to the mode of operation of that apparatus result in any further development of your conceptions, and if so, what?

Ans. It did. I realized the fact that the mechanical vibration of one of the reeds (say A) in the apparatus shown in Fig. 15 would produce on the line wire an undulatory current of electricity, in which the undulatory movements of the current would correspond to the undulatory movements of the reed (A). That is, that the direction or polarity of the current would correspond to the direction of the motion of the reed (A), — being positive when the reed moved in one direction, and negative when it moved in the other; and that the intensity of the current would correspond, from moment to moment, to the velocity of the movement of the inducing reed (A), so that the current would be strongest when the reed moved most rapidly, and weakest at the moment of slowest motion. Having realized that this was the character of the electrical current produced by the vibration of one of the reeds, I next considered what effect would result from the simultaneous vibration of two or more reeds like those shown in Fig. 15. I imagined to myself both reeds — A and B — (which were of different pitch) to be set simultaneously in vibration by a current of wind. Under these circum-

stances the reeds would sometimes be moving in the same direction, and sometimes in opposite directions. Suppose that each reed moved in such a direction as to produce upon the line wire an impulse of positive electricity, then the combined action of both reeds at the same time should produce a positive impulse of greater strength than if either moved alone. On the other hand, if the motion of one reed tended to produce a positive impulse at the same time that the motion of the other reed induced a negative effect, then the reeds would tend to neutralize each other's action. Only a residual effect would appear upon the line wire, which would be positive or negative according to which reed produced the strongest effect. While, then, both reeds are producing electrical effects of the same kind — that is, both positive or both negative — the resultant effect upon the line wire should be the sum of the two impulses; but at the time when the reeds are producing electrical effects of opposite kind — one positive and the other negative — the resultant effect upon the line wire should be the difference of the two. If we should represent graphically, by a curve, the movement of the one reed, A, while producing its musical tone; and by another curve, the movement of the other reed, B; these curves would also represent in a graphical manner the electrical variations produced in the circuit by the vibration of each reed. The resultant electrical effect produced upon the line wire by the simultaneous vibration of both reeds would then be expressed by a curve representing the algebraical sum of the two curves considered. Thus: If the undulatory current produced by the vibration of the reed A (Fig. 15 of the preliminary statement in the *Harmonic Telegraph Interferences*) should be represented by the sinusoidal curve A (shown in Fig. 4 of my patent of March 7, 1876),* and the current produced by the vibration of the reed B (Fig. 15) should be represented by the sinusoidal curve B (Fig. 4 of the patent), then the resultant effect upon the line wire, of the simultaneous vibration of both of the reeds A and B (Fig. 15), is expressed by the resultant curve $A+B$ (Fig. 4 of the patent), which is the algebraical sum of the two sinusoidal curves A and B.

As I was familiar with Helmholtz's researches and with the method of studying composite vibrations by means of graphical curves, I

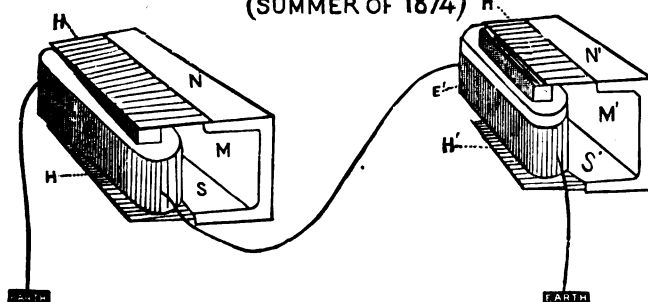
* The Bell patents are at the end of the deposition.

realized at this time (summer of 1874) that the resultant electrical effect produced upon the line wire by the simultaneous vibration of both the reeds A and B (Fig. 15) would be graphically expressed by a curve that would also express in a graphical manner the vibratory movement of the air while the reeds were producing their musical tones. I was much struck by the idea of a likeness between the electrical changes on the line wire (Fig. 15) and the aerial changes produced by the vibration of the same reeds, and began to study the resemblances more closely. I saw that the effect was not confined to the operation of two reeds like those shown in Fig. 15, but that a similar result would follow if we had a multitude of reeds of different pitch, forming a regular musical instrument, each reed having its own electro-magnetic coil, and all the coils being connected in one circuit. That is, I saw that the simultaneous vibration of any number of the reeds would produce upon the line wire a single electrical effect, — the resultant of the effects induced in the different coils; and that the curve that should graphically express this resultant would also represent in a graphical manner the resultant aerial effect produced while the reeds considered were emitting their musical tones. This led to the conception of an improvement in the form of the apparatus considered. The thought occurred — instead of an electro-magnetic coil for each reed employed, why not have one electro-magnet for the whole, and let the resultant effect be induced in the coil of the electro-magnet itself, instead of inducing separate impulses in distinct and separate electro-magnets, and then combining the whole into a resultant upon the circuit? In this way originated in my mind the conception of the “harp” apparatus shown in Fig. 16 of my preliminary statement in the *Harmonic Telegraph Interferences*.

A series of steel reeds was to be arranged so as to form a sort of harp, H, H, each reed having a different pitch. One end of each reed was to be in magnetical contact with one pole of a permanent magnet M, a single permanent magnet being employed for all the reeds. An elongated electro-magnet E was to be placed between the two series of reeds, so that the free end of each reed might be pretty close to the pole of the electro-magnet without touching it. A similar harp arrangement was to be used at either end of the cir-

cuit, and each instrument was capable of employment either as a transmitter or receiver. It was obvious to me that if one of the reeds of the harp H should be thrown mechanically into vibration — as, for example, by plucking it with the finger — electrical undula-

Fig. 16.
BELL'S PRELIMINARY STATEMENT,
HARMONIC TELEGRAPH INTERFERENCES.
(SUMMER OF 1874)



tions would be induced in the circuit, and the corresponding reed of the harp H' would be thrown into vibration by the varying attraction of the electro-magnet E', so that a musical tone would be produced by the harp H', of similar pitch to that produced by the plucked reed of the harp H. I also saw that a very forcible vibration of the reed of the harp H should produce a more violent electrical effect upon the circuit than if the reed were vibrated with less force, because the intensity of the current produced by the magnetized reed depended upon the velocity of the movement of the reed. Of course, the more violent the electrical changes on the circuit, the more violent should be the vibration of the receiving reed of the harp H'.

Hence the musical tone produced from the harp H' should correspond to that produced by the harp H, not only in pitch, but in loudness. That is, the greater the amplitude of the vibration of the reed of the harp H, the louder should be the sound produced by the receiving reed of the harp H'; and the less the amplitude of the transmitting reed, the more feeble should be the sound produced by the receiving reed. While the amplitude of the receiving reed might be absolutely much less than that of the transmitting reed, I saw

that variations in the amplitude of the transmitting reed would cause corresponding variations in the amplitude of the receiving reed; so that variations in the loudness of the sound produced by the receiving reed would correspond to variations in the loudness of the sound of the transmitting reed. Hence I saw that in the operation of such an apparatus as that shown in Fig. 16, simultaneous vibration of two or more of the reeds of harp H would not only cause the vibration of the corresponding reeds of harp H', but that the amplitude of vibration of the receiving reeds would be controlled and determined by the amplitude of vibration of the transmitting reeds. That is, not only would harp H' produce musical tones of similar pitch to those emitted by the vibrating reeds of harp H, but the relative loudnesses of the sounds would be preserved.

Before the summer of 1874 I was familiar with the fact that the strings of a piano could be set into vibration by the action of the voice. For example, depress the pedal of a piano so as to raise the dampers from the strings, and then sing into the instrument. That string which corresponds in pitch to the note sung will respond. In a similar manner it occurred to me that the reeds of the transmitting harp — say H, Fig. 16 — could be operated by means of the voice, or by means of musical sounds of any sort made in the neighborhood of the harp. Sing to the harp as you would sing to a piano, and a similar effect would be produced. The reed of the harp H corresponding in pitch to the tone of the voice should be thrown sympathetically into vibration by the action of the air; and the reed of the harp H', corresponding in pitch, should respond. Now I was familiar with the fact that when we sing a vowel-sound into a piano, while the pedal is depressed, the piano reproduces, not only the pitch, but approximately the quality of the vowel uttered; and, therefore, I saw that a similar effect should be produced by the harp apparatus shown in Fig. 16. If we were to sing a vowel-sound to the reeds of the harp H, the reeds of the harp H' should reproduce, not only the pitch of the voice, but, approximately, the vowel quality. My knowledge of Helmholtz's researches led me to consider that the *modus operandi* of the instruments shown in Fig. 16 would be as follows: When we sing a vowel-sound, the sound produced is composite in character, consisting of a loud fundamental tone mingled

with very feeble tones of higher pitch — over-tones or partial tones, as they are sometimes termed. Upon singing a vowel-sound to the reeds of the harp H (Fig. 16), I saw that the reed corresponding in pitch to the fundamental tone of my voice would be thrown into vigorous vibration; and the reeds corresponding in pitch to the partial tones or over-tones characteristic of the vowel uttered would be thrown into feeble vibration. The corresponding reeds of the harp H' should respond, the amplitude of the vibration of each reed being dependent upon the amplitude of vibration of the transmitting reeds of the harp H. Thus the receiving reeds of harp H' should produce a loud fundamental, and feeble over-tones, corresponding in pitch to the fundamental and over-tones of the voice in uttering the vowel-sound, and the relative loudnesses of the tones would be preserved. Hence the receiving harp H' should reproduce the quality of the sound that actuates the reeds of harp H. In such an arrangement as that shown in Fig. 16 I saw that the reproduction could only be approximate on account of the small number of reeds employed; and I further saw that if the reeds were multitudinous in number, with very slight differences of pitch between adjoining reeds, the reproduction of quality would be exact, and not simply approximate, so that whatever sound should be made or uttered in the neighborhood of harp H would be echoed in *facsimile* from harp H'; and if we spoke words to harp H, the reeds of harp H' would utter words and reproduce the articulation of the speaker. In this way, I realized, in the summer of 1874, the conception of a speaking telephone, and the apparatus shown in Fig. 16 is the first form of speaking telephone that occurred to my mind.

[The words "In this way, I realized, in the summer of 1874, the conception of a speaking telephone . . ." objected to by the counsel for complainant as incompetent and argumentative.]

Int. 35. Did you ever actually construct a harp apparatus, such as you have described in connection with Fig. 16 of your preliminary statement in the *Harmonic Telegraph Interferences*, and if not, what mechanical difficulties were obvious?

Ans. I did not, because it seemed to be impracticable, as a matter of fact, to construct an apparatus with the multitudinous reeds that theory required.

Int. 36. What form did the electric speaking telephone next take in your mind, and what relation had it to the preceding conception of the harp apparatus?

Ans. In studying the theoretical operation of the harp arrangement shown in Fig. 16, while transmitting the quality or *timbre* of a sound, I was led to the conception of a great simplification of the apparatus employed. The action of the voice, as I conceived it, caused the simultaneous vibration of certain of the reeds of harp H, with different degrees of force corresponding to the fundamental and over-tones of the voice; but as there was only one electro-magnet, a single resultant electrical effect was produced in the coil of the electro-magnet. It occurred to me that this resultant effect could equally well be produced by a single reed if forced to move in the resultant path.

My experiments with the manometric capsule and phonautograph had rendered me familiar with the fact that whatever speech-sounds might be uttered, and however many sounds might be produced in the same room, at the same time, the particles of air transmitting the sound or sounds performed only a single vibration, which was a resultant of all the movements transmitted; and I had for a long time past been studying the character of this resultant movement of the air during the production of speech-sounds, as exhibited graphically in the forms of the flame-undulations of the manometric capsule and the shapes of the vibrations recorded by the phonautograph. In considering the operation of the harp apparatus (Fig. 16) I saw there was a single resultant vibration in the air in the neighborhood of the harp H, when a person uttered a vocal sound, and there was a single resultant electrical effect in the circuit, which corresponded in character to the aerial vibration; so that the same shaped curve which should graphically express the aerial effect would also express, in a graphical manner, the electrical effect upon the circuit. It was obvious, then, that a single reed would do the work if it, also, could be vibrated in the resultant manner; so that the same shaped curve that expressed the aerial vibration and the electrical effect, should also express, in a graphical manner, the vibration of the reed. All that appeared to be necessary was, it seemed to me, that one of the reeds, instead of being arranged as a free tuned

reed having a rate of vibration of its own, should be forced to move as the air moved, during the production of a sound. It should then, by its own motion in front of the electro-magnet, occasion electrical changes corresponding to the aerial changes that characterized the given sound. The problem that then arose in my mind was, how to move a piece of steel in the way that the air was moved by the action of the voice. While this problem was in my mind, I was carrying on experiments with the phonautograph constructed from the human ear which Dr. Blake had prepared for me. I do not think that the membrane of this ear could have been half an inch in diameter, and it appeared to be as thin as tissue paper. I was much struck by the disproportion in weight between the membrane and the bones that were moved by it; and it occurred to me that if such a thin and delicate membrane could move bones that were, relatively to it, very massive indeed, why should not a larger and stouter membrane be able to move a piece of steel in the manner I desired? At once the conception of a membrane speaking telephone became complete in my mind; for I saw that a similar instrument to that used as a transmitter could also be employed as a receiver. I proposed to attach the free end of a reed — like one of those shown in Fig. 16 — to the centre of a stretched membrane, the other end of the reed to be hinged loosely to the membrane support, the steel reed to take the place of the wooden lever used in the Morey phonautograph. Instead of being firmly attached to the pole of the permanent magnet — like the reeds shown in Fig. 16 — the pole of the permanent magnet was simply to be brought into close proximity to the hinged end of the reed so as to polarize it. A similar instrument was to be used as a receiver. The arrangement thus conceived in the summer of 1874 was substantially similar to that shown in Fig. 7 of my patent of March 7, 1876. At that time, however, I did not contemplate the employment of a battery upon the circuit, but intended to magnetize the reed *c*, Fig. 7, by the action of a permanent magnet. I proposed that *d* should be the permanent magnet; but I cannot now recall whether or not I intended to have the electro-magnet *b* in contact with the other pole of the permanent magnet *d*, but think that I so intended. If we suppose *d* and *k* (Fig. 7) to be permanent magnets, and the battery to be omitted from the circuit, the diagram Fig.

7 will then show fairly well the membrane speaking telephone as conceived by me in the summer of 1874. I did not give consideration, however, to the artificial appliances, A, L, to aid the voice in concentrating sounds upon the transmitting membrane, and to aid the ear in perceiving sounds emitted by the receiving membrane.

Int. 36. Did you describe the method of transmitting articulate speech electrically, which you had thus conceived, and the apparatus for carrying it into effect — and if so, whom do you recall to mind as having been spoken to upon the subject during the remainder of the year 1874?

Ans. I described it to my father in Canada in July, 1874. Upon my return to Boston that autumn, I described it to Mr. Thomas Sanders, of Haverhill, Mass., and to the Honorable Gardiner G. Hubbard, of Cambridge, Mass. About the end of October, 1874, I described it to Dr. Clarence J. Blake, of Boston; and still later in the year to Professor Charles R. Cross, of the Institute of Technology, Boston. I also described it to other friends in Canada and the United States, during the period specified.

Int. 37. Did you take any steps at that time towards constructing the apparatus which you had conceived for transmitting articulate speech electrically — and if not, what was the reason?

Ans. I did not. While I was satisfied that the apparatus conceived constituted a theoretically perfect speaking telephone, I had the idea that magneto-electric currents, generated by the action of the voice alone, would be so feeble that it was extremely problematical that they would be competent to produce distinctly audible effects from a receiving telephone, on a real line. In the fall of the year 1874, after my return to Boston, Mr. Sanders and Mr. Hubbard became interested in my inventions, and by their advice I devoted my time chiefly to developing my system of multiple telegraphy, as they believed that that invention would prove the most profitable.

Int. 38. In your application, filed February 25, 1875, and relating to Harmonic Multiple Telegraphy, you used the following language:

“I prefer to produce the intermittent current by actual make and break contact. But the result may be attained by alternately diminishing and increasing the intensity without absolute break in the continuity of the current.”

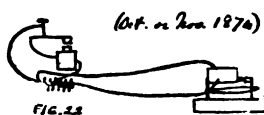
Had you previously employed currents of this latter description, and if so, by what particular arrangement of transmitting apparatus?

Ans. I had. One arrangement of apparatus is shown in Fig. 22* of the drawings in my preliminary statement in the *Harmonic Telegraph Interferences*; in which the circuit-interrupter, in vibrating, short-circuits a portion of the battery, so that the intensity of the current on the main line, passing through the receiving instrument, is suddenly diminished and increased by the operation of the transmitting instrument, without absolute break in the continuity of the current. In operating the arrangement of circuit shown in Fig. 22, it was intended that a telegraph-key should be inserted on the main line, between the transmitting and receiving instruments. The elevation of the telegraph-key would break the circuit containing the receiver so that, at such a time, no current would appear upon the main circuit, but the armature of the transmitter would remain in continuous vibration, even when the main circuit was broken, as a portion of the battery was directed through the electro magnet of the transmitting instrument. Upon depressing the telegraph-key, the main circuit would be completed, as shown in the diagram Fig. 22. Under these circumstances the armature of the transmitting instrument would vibrate as before, making and breaking contact with the end of a set-screw. When it broke contact, the whole battery was in circuit with the main line. When it made contact, a portion of the battery formed part of a local circuit passing through the electro-magnet of the transmitter, thus weakening the current of the main line. So that while the key was depressed, there was always a current upon the main line, and it simply changed suddenly in strength at every vibration of the transmitter.

Other arrangements producing a similar result are illustrated in Figs. 20 and 21.

Int. 39. In the same application of February 25, 1875, you used the following language :

*



"I prefer to use, for each transmitter, a receiver composed of an electro-magnet and an armature which will be thrown into a state of vibration by the impulses sent through the electro-magnet. But other arrangements for the purpose may be devised. For instance, with a series of transmitters organized as above indicated, I can place at the receiving end of the line a telephone from the rod of which silk threads may lead to a series of bodies such as tuning-forks capable of definite vibration, each one of these bodies having a rate of vibration corresponding to one, and one only, of the transmitters. In case two or more different sets of impulses be transmitted simultaneously to the telephone, each will affect that one alone of the tuning-forks, whose vibrations are synchronous with the impulses.

The same effect could be produced by resonators of different pitches placed under the rod of the telephone."

To what instrument did you therein refer as a "telephone"?

Ans. I alluded to the receiving instrument of the Reis telephone.*

Int. 40. Where and when had you previously become acquainted with the receiving instrument of the Reis telephone?

Ans. I think it was in November, 1874, one of the professors of the Institute of Technology — probably Professor Cross — told me of the Reis telephone, and I think he may have shown me, at the Institute of Technology, a Reis receiver.

Int. 41. It appears by the testimony of Professor Cross, in the present suit, that his recollection of the time when he showed you

* Philip Reis, of Friedrichsdorf, Germany, about 1861, made an apparatus which he called a "telephone," which by alternately making and breaking an electric circuit could transmit musical tones. Reis's work was fully described in contemporaneous printed publications, and a great quantity of documentary and expert evidence was offered by various defendants in the telephone litigation to support the contention that Reis was a prior inventor. Another contention was that if Reis had not invented a speaking telephone he had made such progress in the art, that Bell's telephone was a mere improvement in construction; and numerous so-called Reis telephones were made which, when operated by the method taught by Bell's patent, could be made to transmit speech. The Reis defence, a though urged with great persistency in numerous cases, never found favor with the courts. In the *Spencer* case, decided in 1881 (8 Fed. Rep. 509), Judge Lowell said:

"A century of Reis would never have produced a speaking telephone by mere improvement in construction."

The Supreme Court in *The Telephone Appeals* considered the Reis defence at length, and decided (126 U. S. 544):

"It was left for Bell to discover that the failure was due not to workmanship, but to the principle which was adopted as the basis of what had to be done. . . . To follow Reis is to fail, but to follow Bell is to succeed."

the receiver of a Reis telephone was somewhat earlier in the year 1874 than you have thought it to be. If you have any reason for assigning the date which you have, will you state it?

Ans. My impression is that Professor Cross did not tell me about the Reis telephone until on or after the twenty-sixth day of November, 1874; but the time is so long ago that I cannot be certain of more than this: that, if he had told me about it before, it had made little or no impression upon my mind. My reason for asserting this is the fact that, on November 26, 1874, I discovered that a sound was emitted by the solid iron core of an electro-magnet when placed in circuit with one of my current-interrupters. And in a letter to Mr. Hubbard of that same date (November 26, 1874), a copy of which was put in evidence in the case of the *well Telephone Co. v. Peter A. Dowd*,* I spoke of this discovery as entirely original with myself. In my letter to Mr. Hubbard, I said:

"I have been reflecting all the evening upon the *cause* of this strange phenomenon, and I think that I have discovered it. The solution, if correct, points to other still stranger phenomena. My idea is this: When a current of electricity passes through the coils of an electro-magnet, the molecules of iron in the core become magnetic and attract each other, approaching nearer together than they were. When the current stops, they resume their former places. This is borne out by the fact (that I have read somewhere) that a soft iron bar becomes *shorter* on being magnetized. Hence an intermittent current of electricity passed through the coils of an electro-magnet should induce a *molecular vibration* in the core; and perhaps this molecular vibration may have been the cause of the sounds heard by me this evening."

My impression is that I knew nothing of the Reis telephone before this experiment, and that I repeated the experiment in the presence of Professor Cross and other friends, and that he then told me that the effect had been discovered before by Philip Reis, and then gave me my first information concerning the Reis telephone.

Int. 42. You have already referred to the fact that your application of March 10, 1875, relating to harmonic multiple telegraphy, describes a receiver in which two steel-spring armatures are kept permanently magnetized by being attached to the poles of a permanent magnet. Had you, previously to the date of filing that ap-

* This is the *Dowd* suit referred to in the Introductory Memorandum.

plication, constructed and employed a receiving instrument in which the free reed, to be set in vibration by an electro-magnet so as to produce a musical tone, was attached to the pole of a permanent magnet, and thereby kept permanently magnetized?

Ans. To the best of my recollection, I had constructed such an apparatus before the date of the application referred to.

Int. 43. The same application, of March 10, 1875, contains the following language :

"I have created a regular oscillation of the induced current by means of permanent magnets in the place of batteries. Bar magnets G, with poles arranged as shown, were placed on the surface of a revolving cylinder with several electro-magnets E placed opposite to them, as shown in Fig. 4, the space between any two adjoining magnets being equal in breadth to the pole of the electro-magnet opposed to it.

Under this arrangement, when the cylinder was revolved, direct and reversed induced currents came at equal intervals apart, making electrodes of the earth and line wires *a*, *b*. With this instrument, the induced currents passed directly through the ears, created in the ear itself the perception of a musical note, without the intervention of any receiving instrument whatever."

I find, on referring to the drawings, that two corrections need to be made in this description, viz. : "bar magnets G" should be "bar magnets M"; and "Fig. 4," should be "Fig. 3." Had you, previously to filing this application, made the experiment thus described, and if so, when and how do you determine the circumstance and date?

Ans. The bar magnets on the surface of the revolving cylinder alluded to in the specification are shown in Fig. 3, and not Fig. 4, as stated in the specification; and are marked M, and not G. I made the experiment described on the fifteenth day of December, 1874, and described it on the same day, in a letter to Dr. Clarence J. Blake, the original of which is now before me, and is as follows :

SALEM, MASS., December 15th, '74.

MY DEAR SIR :

I have been unwell for some days past or I should have written to you.

I have this afternoon made a curious discovery, if indeed further experiment confirms it, and I want your assistance in the matter.

When we take hold of the handles of an ordinary electro-magnetic

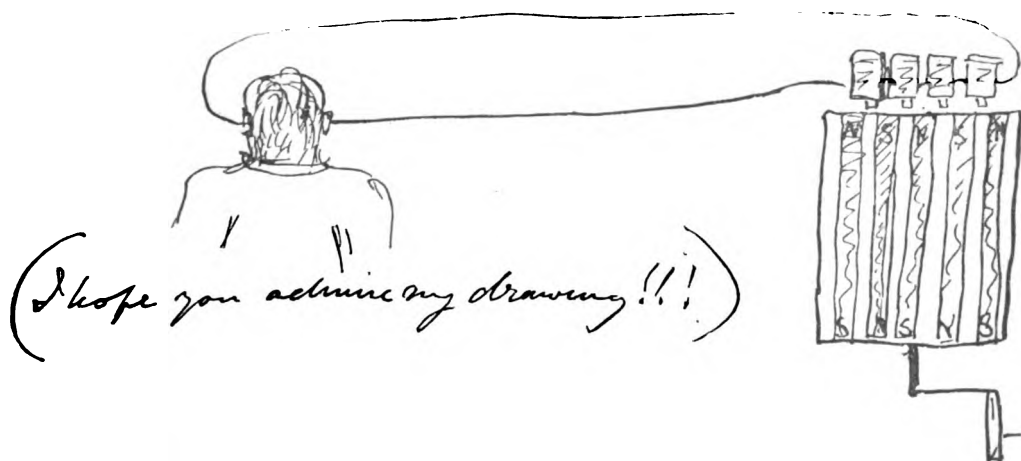
machine, the muscles of our arms are made to *vibrate* at a rate corresponding to the making and breaking of the primary circuit.

Now the thought struck me that if we could make the direct and reversed induced impulses succeed one another as regularly as the crests and depressions of waves, then an electrode applied to the ear so as to induce a vibration in the membrane tymp. *should create the sensation of sound without the aid of any intermediate apparatus.*

I have had an instrument made and the experiment seems a success.

A number of permanent magnets were arranged upon a cylinder, which was revolved in front of electro-magnets.

[See illustration.]



On filling my ears with water and applying the wires (protected of course) as in the diagram, a soft musical note was heard. The sound stopped the moment the electrical circuit was broken. The wires employed were very short, so that the noise of the rotating cylinder (conducted mechanically along the wire) almost drowned the musical note. The latter thus appeared like an *over-tone*.

Two ladies who were present submitted to the experiment and heard the note as clearly as I did. A gentleman, however (who could not distinguish over-tones in music), heard nothing more than the *noise*.

I want your co-operation. Can we arrange for a meeting on Saturday morning at your rooms? I am anxious to see the results of your experiments.

Yours sincerely,

A. GRAHAM BELL.

DR. C. J. BLAKE,
Hotel Berkeley.

Int. 44. Where were the specifications of your applications of February 25, 1875, March 6, 1875, and March 10, 1875, respectively, prepared?

Ans. In Washington, D. C.

Int. 45. When did you visit Washington for that purpose?

Ans. From a letter written to my father, from Boston, dated Friday, February 12, 1875, I find that I proposed to start for Washington on "Monday morning," the 15th of February, 1875. I presume that I did so, and therefore reached Washington probably on Tuesday the 16th of February, 1875.

Int. 46. It appears from the certified copy of your application, filed March 10, 1875, which has been put in evidence, that you made oath to the specification thereof on March 2, 1875, before Henry R. Elliott, United States Commissioner for the District of Columbia. Did you remain in Washington continuously from about February 16, 1875, to March 2, 1875?

Ans. To the best of my recollection, I did.

Int. 47. Were you acquainted with the late Professor Joseph Henry, who, during a considerable number of years preceding his death, was secretary of the Smithsonian Institution at Washington, and if so, when did you first become acquainted with him?

Ans. I think I first became acquainted with him during the visit to Washington referred to in the last preceding answer; probably about the end of February or beginning of March.

Int. 48. Have you any nearly contemporaneous written memoranda relating to your first acquaintance with Professor Henry, and if so, when, and of what date?

Ans. I have. They are contained in a letter written to my parents from Salem, Mass., dated March 18, 1875, the original of which I have before me.

Int. 49. Will you please read that letter, omitting only merely personal and family matters?

Ans. I read from it the following:

292 ESSEX ST., SALEM, March 18, 1875.

DEAR PAPA AND MAMMA:

I have just returned from my trip to New York thoroughly worn out. Found your letters of the 14th inst. awaiting me. I am now

beginning to realize the cares and anxieties of being an inventor. In order to complete the apparatus as thoroughly as possible, I have decided to give up all professional work for some weeks. I have put off all pupils and classes until the 12th of April. Flesh and blood could not stand much longer such a strain as I have had upon me. Professional work is all in confusion, and the only way is to cut the Gordian knot and throw up everything until the end is achieved. I long to write full accounts to you, and I have delayed writing in order to give a connected narrative of the whole. You seem to think that my anxieties are over, when in truth they are really only beginning.

Before entering upon explanations, let me ask you first to hunt over all my old letters that you have preserved, for everything bearing on the Telegraph. Forward to me at once as evidence. I must take action at once in regard to foreign patents. Will you or uncle help me in this.

What I would like is this: I have written to my lawyers in Washington to make application for foreign patents on my own responsibility.

Should I prove unable to pay for these applications at once, will you help me? While these applications are being got out I shall write to the Herdmans offering them a share if they will take the pecuniary burden of any interference, etc., that may arise abroad from Mr. Gray. Should they decline—which I should think unlikely—I should, of course, relinquish a foreign contest.

Whenever I am free to dispose of my interest in the invention I shall do so, and then you may expect to see Visible Speech go ahead. I can then take up the electric motor, which I think as valuable an idea as this telegraph.

. . . Now, to resume telegraphy. When I was in Washington I had a letter of introduction to Professor Henry, who is the Tyndall of America. I had found on inquiry at the Institute of Technology, that some of the points I had discovered in relation to the application of acoustics to telegraphy had been previously discovered by him. I thought I would, therefore, explain all the experiments, and ascertain what was new and what was old. He listened with an unmoved countenance, but with evident interest to all, but when I related an experiment that at first sight seems unimportant, I was startled at the sudden interest manifested.

I told him that on passing an intermittent current of electricity through an empty helix of insulated copper wire, a noise could be heard proceeding from the coil, similar to that heard from the telephone. He started up, said, "Is that so? Will you allow me, Mr. Bell, to repeat your experiments, and publish them to the world through the Smithsonian Institute, of course giving you the credit of the discoveries?"

I said it would give me extreme pleasure, and added that I had

apparatus in Washington, and could show him the experiments myself at any time. He asked if I could do it *then*, if he went with me, and I told him that I had everything in readiness at Mr. Hubbard's house. He said, "I will go with you now. Have you a carriage here?" I had not, and so he put on his coat and was about to order his carriage, when I offered to save him the trouble of going out on such a raw, damp day, by bringing the apparatus to the Smithsonian Institute. (He was suffering from a cold, and besides is very aged, — I believe about eighty years old.)

We appointed noon next day for the experiment. I set the instrument working and he sat at a table for a long time with the empty coil of wire against his ear listening to the sound. I felt so much encouraged by his interest that I determined to ask his advice about the apparatus I have designed for the transmission of the human voice by telegraph. I explained the idea and said, "What would you advise me to do, publish it and let others work it out, or attempt to solve the problem myself?" He said he thought it was "the germ of a great invention," and advised me to work at it myself instead of publishing. I said that I recognized the fact that there were mechanical difficulties in the way that rendered the plan impracticable at the present time. I added that I felt that I had not the electrical knowledge necessary to overcome the difficulties. His laconic answer was, "GET IT."

I cannot tell you how much these two words have encouraged me. I live too much in an atmosphere of discouragement for scientific pursuits. Good —— is unfortunately one of the *cui bono* people, and is too much in the habit of looking at the dark side of things. Such a chimerical idea as telegraphing *vocal sounds* would indeed to *most minds* seem scarcely feasible enough to spend time in working over. I believe, however, that it is feasible, and that I have got the cue to the solution of the problem.

Professor Henry seemed to be much interested in what I told him, and cross-questioned me about my past life, and specially wanted to know where I had studied physics. . . .

Having left Professor Henry and Washington I proceeded to New York, where I saw Mr. Orton and Mr. Prescott, the electrician. Arrangements were made for me to bring my instruments to New York and experiment on a real line wire.

I left Boston last Sunday and called at the office of the Western Union on Monday. Mr. Orton and Mr. Prescott both devoted a large portion of their time in discussing with me the whole plan from its theoretical point of view. Mr. Smith, the manager of the experimental room, was absent from town, but was telegraphed for. He replied that he could not come till next morning. Tuesday forenoon we had Batteries connected and I tuned up my instruments. They went like clock work. I have come to the conclusion that by a happy chance they are much more perfect than I thought at first.

The signals were as clear, sharp and rapid as with the ordinary Morse sounder. I connected two Transmitters and two Receivers on only one line and two messages were sent simultaneously.

We had 100 cells of a battery, and all went well on our artificial circuit. Mr. Prescott then said he would like to see them tried on a real line wire. He telegraphed to Philadelphia to have two wires crossed there so as to give us (practically) a continuous wire from New York to Philadelphia and back. The electro-magnets I employed were not intended for trial on a long line. They were wound with coarse wire and the "resistance" was only "3 ohms." Ordinary electro-magnets for actual service on a line have a resistance of about 200 to 600 ohms. None of us, therefore, expected the instruments to work without stronger magnets. But they *did work*.

The signals, though feeble, came sharply and concisely through the 200 miles of line wire. I suggested trying stronger magnets, so Mr. Prescott ordered the instruments to be taken to the workshop and stronger magnets placed on them. They were to be ready in the afternoon, so I went out to dinner and returned in a couple of hours.

Rest will form subject for next letter.

With fond love,

Your ever affectionate son,

ALECK.

PROFESSOR A. M. BELL,
Brantford, Ontario.

Int. 50. Are the statements contained in the letter of March 18, 1875, to your parents, which you read just before the last adjournment, concerning your interviews with Professor Joseph Henry, correct and true accounts of what took place and of the conversations had between you?

Ans. They are.

Int. 51. And are the other matters related in the same letter, concerning your own experience, also true statements of what took place?

Ans. They are.

Int. 52. Considering the fact that you were in Washington on March 2, 1875, as shown by the date of the oath to your application of March 10, 1875, and the expression used by you in your letter of March 18, 1875, where you said —

"Having left Professor Henry and Washington, I proceeded to

New York," etc., are you able to fix more definitely the dates of your interviews with Professor Henry, mentioned in that letter?

Ans. I think I can. My recollection is that my second interview with Professor Henry, mentioned in the letter, occurred during the last day of my stay in Washington, and on the same day when I took oath to the specification referred to. That is, the second interview took place on the second day of March, 1875, and the letter shows that the first interview took place the preceding day, March 1, 1875.

Int. 53. Who were Mr. Orton and Mr. Prescott, mentioned in that letter; and what was the general character of the apparatus which you exhibited to them?

Ans. Mr. Orton was president of the Western Union Telegraph Company, and Mr. Prescott was electrician of the same company. I exhibited multiple telegraph apparatus.

Int. 54. In the same letter, referring to your first interview with Professor Henry, you stated:

"I told him that on passing an intermittent current of electricity through an empty helix of insulated copper wire, a noise could be heard proceeding from the coil, similar to that heard from the telephone."

Was the telephone thus mentioned made the subject of any further conversation between you on that day, or at a subsequent date, and, if so, to what specific apparatus did you both refer?

Ans. We both referred to the Reis telephone. We had some further conversation upon that subject, either on that day or the subsequent one. I cannot now recall the details of what was said, and remember simply that Professor Henry illustrated his remarks by showing me the Reis telephone itself. He had, at the Smithsonian Institution, both the Reis transmitter and the Reis receiver, and he showed them to me, either on the 1st or 2d of March, 1875.

Int. 55. There have been put in evidence translations of several printed publications relating to the Reis telephone, among which are Reis's Circular of August, 1863; Reis's Descriptive Circular, 9th August, 1863, and *Die Gartenlaube*, December, 1863. Will

you look at the pictures of the Reis apparatus * contained in these three publications, and state how the apparatus shown in each compares in form and construction with the apparatus which Professor Henry showed you at the Smithsonian Institution, March 2, 1875?

Ans. They seem to be drawings of the Reis apparatus shown to me by Professor Henry.

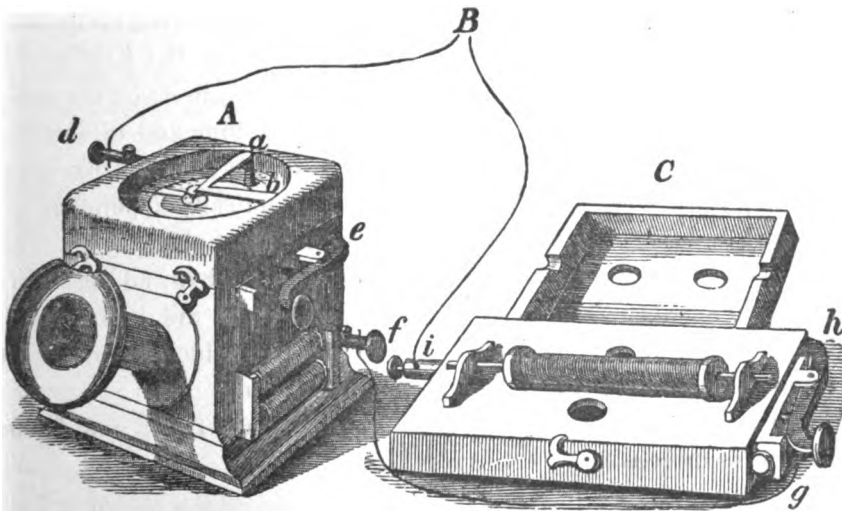
Int. 56. Have you since Professor Joseph Henry's death received any further corroboration of your recollection that your interview with him when you exhibited the production of sound in an empty helix of insulated wire, by passing an intermittent current of electricity through it, was March 2, 1875?

Ans. I have. Miss Henry, daughter of Professor Henry, sent me the following extract which she found in her father's journal, under the date of March 2, 1875:

"Experiments with Mr. A. Graham Bell, of Boston, on the sound made by an interrupted current passing through a cylindrical coil of wire without an iron core . . ."

Int. 57. Do you remember discussing with Professor Henry, on March 2, 1875, in connection with the apparatus which you had designed for the transmission of the human voice by telegraph, any

* This is the drawing referred to. See 126 U. S. 60.



specific subject other than that mentioned in your letter of March 18, 1875?

Ans. I remember asking his advice regarding the use of a stretched membrane in an apparatus substantially similar to that shown in Fig. 7 of my patent of March 7, 1876. I remember this from the fact that I received but little encouragement from Professor Henry regarding the use of a stretched membrane. I do not now remember what was said upon the subject, but I carried away the impression that Professor Henry thought a stretched membrane would have a rate of vibration of its own, and that this would be a difficulty in the way of utilizing the stretched membrane for the purpose I desired.

Int. 58. In your letter of March 18, 1875, you referred to your cares and anxieties as an inventor, and to your putting off your pupils and classes. What professional arrangements had you made which you were thus obliged to put off, and how did your professional business fare the remainder of that season, ending with the summer vacation of 1875?

Ans. I hold in my hand a printed circular of my "School of Vocal Physiology," giving the arrangement of classes for the spring session of 1875, from which I find there were five classes to begin on March 1, 2, and 3, 1875, respectively; and these are the classes mentioned in my letter as having been put off until the 12th of April. I have no means now of ascertaining whether these classes were or were not opened the 12th of April, as intended; but I remember that my professional work was much disorganized, first, by the delay in commencing; and second, by the increasing time and attention I gave to my electrical researches. Indeed, it was so much disorganized as to fail me altogether, until I was practically dependent for support upon the instruction of my little pupil in Salem.

Int. 59. I show you a letter dated May 4, 1875, addressed to Gardiner G. Hubbard, Esq. Did you write it on the date which it bears, and, if so, will you read from it that part which begins at the top of the third page, and from thence to the end.

Ans. I did write it on the fourth day of May, 1875, and I read from it as directed:

SALEM, MASS., May 4th, 1875.

DEAR MR. HUBBARD :

. . . Letter received from Mr. Pope, with directions for preparing paper. Letter received from Prof. Henry of the Smithsonian Institute in answer to one I wrote to him some time ago telling him of recent experiments undertaken in order to determine the cause of the sound heard from the empty helix of wire.

The deduction I had made from the experiments was that an intermittent current of electricity creates a molecular vibration in the conductor through which it is passed. Prof. Henry writes that he believes that my experiments are new, and that my explanation of the cause of the sound is in his opinion correct.

An experiment which I have long desired to make is at last within my reach. My friend, Don Manuel Fenollosa, whose music rooms are next door to this house, is to allow me to experiment with his pianos. I shall carry a wire from my study into his room tomorrow, and try the effect of passing an intermittent current through the strings of a piano. Unless I am greatly mistaken, the string, whose rate of movement coincides with the molecular vibration induced in the wires by one of my transmitters, will resound loudly.

Another experiment has occurred to me which, if successful, will pave the way for still greater results than any yet obtained. The strings of a musical instrument in vibrating undergo great changes of *molecular tension*. In fact, the vibration represents the struggle between the tension of the string and the moving force impressed upon it. I have read somewhere that the resistance offered by a wire to the passage of an electrical current is affected by the *tension of the wire*. If this is so, a *continuous current of electricity* passed through a vibrating wire should meet with a varying resistance, and hence a pulsatory action should be induced in the current. If this turns out to be the case, the oscillations of the current should correspond in *amplitude*, as well as in rate of movement, to the vibrations of the string. One consequence would be that the *timbre* of a sound could be transmitted. The plan for transmitting *timbre*, that I explained to you before, — viz., causing permanent magnets to *vibrate* in front of electro-magnets, — is chiefly defective on account of the feebleness of the induced currents. If the other plan is successful, the strength of the current can be increased *ad libitum* without destroying the *relative intensities of the vibrations*.

Yours respectfully,

A. GRAHAM BELL.

GARDINER G. HUBBARD, Esq.,
Cambridge, Mass.

Int. 60. In this letter of May 4, 1875, mention is made of Mr.

Pope, in connection with directions for preparing paper. Who was he, and for what purpose was the paper to be prepared?

Ans. Mr. Frank L. Pope. I think he was an electrician employed by the Western Union Telegraph Company. The prepared paper was for use in my system of autograph telegraphy.

Int. 61. Did you try the experiment of passing an intermittent current through the strings of a piano, as mentioned in this letter?

Ans. I think I did, but cannot remember the details of the experiment with any distinctness. My recollection is that I found the construction of the piano unsuited for the experiment desired, the strings being metallically connected together by the framework of the instrument. I am quite sure, however, now I come to think of it, that I did make some experiments with Mr. Fenollosa's piano, in pursuance of the idea mentioned in the letter.

Int. 62. Did you ever try the other experiment mentioned in your letter of May 4, 1875, to ascertain the effect of the varying tension of a wire in vibration upon a current of electricity passing through it? And if so, when, and with what result?

Ans. Yes. I tried such an experiment, I think in the year 1879. A continuous current from a voltaic battery was passed through a stretched wire — I think a thin steel wire — which was placed in the same circuit with an ordinary commercial hand telephone. When the wire was plucked by the hand, it vibrated, producing a musical tone. The hand telephone was in another room, and I listened at the telephone while a young man was plucking the wire. I heard a musical tone from the telephone at each pluck, and could recognize, also, that the character or *timbre* of the sound produced by the vibrating wire was reproduced by the telephone at my ear. I made a number of experiments to satisfy myself that the sound was electrically produced, and had not been conducted along the line wire to the telephone. For example, no sound was heard when the circuit was broken nor when the coil of the telephone was short-circuited by a wire connecting the two terminals.

Int. 63. I show you a letter dated May 24, 1875. Did you write it, and, if so, to whom was it addressed and sent?

Ans. Yes. I wrote it on the 24th of May, 1875. It was addressed and sent to my parents.

Int. 64. Will you read it as your answer to the present interrogatory?

Ans. I will. The letter is as follows :

SALEM, MASS., May 24, 1875.

DEAR PAPA AND MAMA :

I am so immersed in telegraphy and science that I find it impossible to write freely about anything else, but I feel that at the present time you can scarcely be inclined to listen to anything I have to say on such subjects.

Since I gave up professional work and devoted myself exclusively to telegraphy, I have been steadily gaining health and strength, and am now in a fit state to encounter Mr. Gray or anyone else. The patents that have been granted to me without opposition are, —

1st. The principle of converting a vibratory motion into a permanent make or break of a local circuit.

2nd. The special form of "vibratory circuit breaker" put in illustration.

3rd. The autograph telegraph.

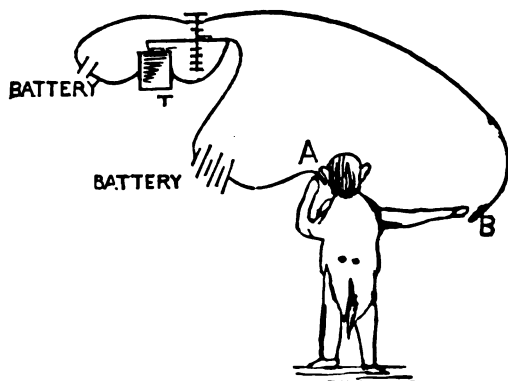
The autograph arrangement is rapidly approaching completion. Already I can copy handwriting *quite legibly*, though not yet neatly. The rate of transmission by means of my instrument will be exactly ten times more rapid than "Bakewell's Autograph Telegraph," in which the rate is 300 letters per minute. When 3000 letters per minute can be sent, my telegraph will be the most *rapid* as well as the *cheapest*.

Every moment of my time is devoted to study of electricity and to experiments. The subject broadens. I think that the transmission of the human voice is much more nearly at hand than I had supposed. However, this is kept in the background just now, as every effort is to be made to complete the autograph arrangement, so as to have it used on some line.

The two patents for the transmission of musical notes are not decided yet. I can't understand why the Interference should not have been declared before this. Here are some late discoveries :

1. The current from one of my instruments passed through an iron wire causes a musical note to issue from the wire. 2. The same effect is produced by passing the current through a piece of carbon. 3. Ditto when it is forced through the plumbago of an ordinary lead pencil. No similar effects noted yet with copper, brass, or mercury.

A still more curious phenomenon is the following :



Two thin strips of brass (A and B) are connected with the wires coming from my Transmitting Instrument, T, and from the Battery. On holding A to my ear I hear nothing, but the moment that I touch B with my finger a musical note is heard to proceed from A!!

Truly, the more I study electricity and magnetism the more I feel the truth of Hamlet's saying, "There are more things," etc.

I fear that this telegraphic business may force me to remain the greater portion of the summer here, but I cannot tell yet, so many details have to be worked out. My inexperience in such matters is a great drawback. However, Morse conquered his electrical difficulties although he was only a painter, and I don't intend to give in either till all is completed.

With dear love,

Yr affectionate son,

ALECK.

Int. 65. I show you another letter, dated June 2, 1875. Did you write it on that day, and, if so, to whom was it addressed and sent?

Ans. Yes. I wrote it on the 2d of June, 1875. It was addressed and sent to Mr. Hubbard.

Int. 66. Will you read it as a part of your present answer?

Ans. The letter is as follows:

SALEM, MASS., June 2d, 1875.

DEAR MR. HUBBARD:

I have accidentally made a discovery of the very greatest importance in regard to the Transmitting Instruments. Indeed, so important does it seem to me that I have written to the Organ Factory to delay the completion of the Reed arrangement until I have had the opportunity of consulting you.

I have succeeded today in transmitting signals *without any battery whatever!*

The musical note produced at the Receiving End was sensibly the equivalent of that at the Transmitting end in *loudness* as well as pitch.

I shall call upon you tomorrow (Wednesday) evening as there are several matters I wish to talk over with you.

In haste,

Yours respectfully,

A. GRAHAM BELL.

GARDINER G. HUBBARD., Esq.,
Brattle St., Cambridge.

Int. 67. Did you, on June 2, 1875, perform the experiment stated in that letter, and if so, where?

Ans. I did. In the electrical establishment of Mr. Charles Williams, Jr., 109 Court Street, Boston.

Int. 68. Please describe more in detail the experiment of June 2, 1875, and the discovery resulting therefrom.

Ans. On the 2d of June, 1875, I was engaged, with the assistance of Mr. Thomas A. Watson, in the operation of tuning and testing certain receiving instruments, preparatory to an experiment I proposed to make with my multiple telegraph apparatus in transmitting three telegraphic messages simultaneously along a single circuit. I had arranged three experimental stations, which for clearness I shall designate as A, B, and C. At station A, I had three circuit-breaking transmitters, which I shall call T, T', T², tuned to different pitches, and three telegraphic keys, K, K', K², for connecting the transmitters with the line wire as desired. At station B were three tuned-reed receivers, R, R', R², having the same pitches as the corresponding transmitters at station A. At station C, I also had three similar tuned-reed receivers, R, R', R². The receivers at station B and C were substantially like the instruments shown in Figs. 5 and 6 of my patent of March 7, 1876. If the instruments were properly tuned and adjusted, then the depression of the key K, at station A, should connect the transmitter T with the line wire, and the receivers R at stations B and C should be thrown into forcible vibration, but not the other receiving instruments. So the depression of the key K', by throwing the transmitter T' into the circuit, should cause the forcible vibration of

the receivers R' at stations B and C; and the depression of K^2 , in a similar manner, should cause the forcible vibration of the receivers R^2 . Stations A and B were in a small room in the upper part of Mr. Williams's establishment, and station C was just outside, in a room on the same floor. When Mr. Watson and I were experimenting with the apparatus, one of us would go into the room containing stations A and B, and operate the keys of the transmitting instruments, and the other would remain just outside the door, in charge of station C. On the occasion referred to, I was in charge of stations A and B, and Mr. Watson was observing the receiving instruments at station C. Our mode of experimenting was as follows: I would depress one of the keys at station A — say key K — and would look at the receivers at station B to see whether the corresponding receiver R was thrown into good vibration. At the same time, Mr. Watson, at station C, would observe whether his receiver R was vibrating well. If the vibrations were not satisfactory, we would tune the proper receivers by shortening or lengthening the free part of the reed armature, according as the pitch was lower or higher than that desired. Sometimes we found that the reed armature was so closely adjusted to the pole of the electro-magnet below it that it would stick to the pole, instead of vibrating, the moment a current was passed through the electro-magnet. We would then cause the armature to be released by plucking it with the finger, and if it still stuck every time a current was passed through the coil of the electro-magnet, we would bend the reed armature so as to cause its free end to be normally a little farther away from the pole of the electro-magnet. On this second day of June, 1875, we were engaged in the process of testing the receiving instruments at stations B and C. I depressed one of the keys at station A — say key K — and observed the corresponding receiver R at station B. It seemed to vibrate well, but Mr. Watson called out that the reed of the corresponding receiver R at station C was sticking against the pole of its electro-magnet. I then told him to pluck it to release it, and he did so. At that moment I happened to have my eye upon the corresponding receiver R at station B, and was surprised to see the reed of that instrument thrown momentarily into powerful vibration at the very time I supposed

Mr. Watson to be plucking the reed of his instrument. I presume that the key K of the corresponding transmitter T at station A was raised, for I did not expect the receiver R to be thrown into vibration at that time. Under these circumstances, the vibration of the reed immediately riveted my attention, and I called out to Mr. Watson to pluck his reed again. He did so, and again the reed of the receiver R at station B was momentarily thrown into vibration. I kept Mr. Watson plucking the reed at his station, C, while I placed the reeds of the receivers at station B successively against my ear. At every pluck I could hear a musical tone of similar pitch to that produced by the instrument in Mr. Watson's hands, and could even recognize the peculiar quality or *timbre* of the pluck. For a long time that day there was little done but plucking reeds and observing the effect. Changes were made in the arrangements of circuit, and Mr. Watson and I frequently changed places. To make perfectly sure that the vibration of the one reed had really been the cause of the vibration of the other, and that the effect had been electrically produced, two receivers having the same pitch were arranged as in Fig. 5 of my patent of March 7, 1876, but without any battery upon the circuit. Upon plucking one of the reeds with the finger, the other was thrown into powerful vibration — vibration so strong as not simply to produce a musical tone, but also to be capable of operating the vibratory circuit-breaker of my patent of April 6, 1875, No. 161,739, and therefore capable of use in my system of multiple telegraphy. These experiments at once removed the doubt that had been in my mind since the summer of 1874, that magneto-electric currents generated by the vibration of an armature in front of an electro-magnet would be too feeble to produce audible effects that could be practically utilized for the purposes of multiple telegraphy and of speech-transmission.

Int. 69. When you tried the experiment of connecting two receivers of the same pitch in circuit, as shown in Fig. 5 of your patent of March 7, 1876, but without a battery, what generated the electrical impulses which caused the reed of one instrument to vibrate when the reed of the other was plucked?

Ans. I presumed at the time, and still think, that, on account of residual magnetism, the steel reed and the core of the electro-magnet

acted as though they were weak permanent magnets, so that the vibration of the reed caused magneto-electric currents in the coil of the electro-magnet.

Int. 70. What had created this residual magnetism in the steel reed and in the core of the electro-magnet of each of those instruments?

Ans. The passage of heavy battery currents through the coils of the electro-magnets in previous experiments.

Int. 71. Did the experiments of June 2, 1875, and the discovery resulting therefrom, lead to any further novel experiments, and if so, will you describe briefly the character of the next one?

Ans. A great many experiments were made on that 2d of June, 1875, and succeeding days. We tried the experiment shown in Fig. 5 of my patent of March 7, 1876, in which a battery was employed to magnetize the cores of the electro-magnets, and the effects appeared to be much improved. That is, the mechanical vibration of one of the reeds seemed to throw the other into more powerful vibration when a battery was employed than when none was used. Other experiments were made with a large horseshoe permanent magnet, shaped like the prongs of a tuning-fork. I could set this in vibration by striking it against a table, and it would then vibrate after the manner of a tuning-fork, producing a musical tone. One of the vibrating prongs would then be held near the pole of an electro-magnet which was in circuit with a tuned-reed receiver, like that shown in Fig. 5 of my patent of March 7, 1876, which was damped by being held against the ear. The vibration of the permanent magnet created magneto-electric currents which produced a perfectly audible musical tone from the receiving reed held closely pressed against my ear, even while there was no battery upon the circuit.

Int. 72. Were the experiments of June 2, 1875, and the discovery resulting therefrom, followed by the construction of any different form of apparatus, and if so, will you describe what you caused to be constructed, and what induced you to construct it?

Ans. The experiments were followed by the construction of a different form of apparatus. The discovery that the vibration of a steel reed in front of the pole of an electro-magnet generated

magneto-electric currents of sufficient power to produce audible effects from a receiver in the same circuit, convinced me in a moment that the membrane speaking telephone I had designed in the summer of 1874 would prove a practicable working instrument. Before the second day of June, 1875, I believed that the instrument was a theoretically perfect speaking telephone, but I had the idea that the currents generated by the action of the voice would be too weak to produce distinctly audible effects from the receiving instrument on a real line. The experiments made on June 2 convinced me that this idea was a mistake, and I immediately gave instructions to Mr. Watson to have two membrane telephones constructed, substantially similar to those shown in Fig. 7 of my patent of March 7, 1876. So far as I recollect now, my instructions to Mr. Watson were to take two of the tuned-reed receivers we had been using, and instead of clamping each reed firmly to the uncovered leg of the electro-magnet, he was to arrange it loosely upon a hinge. The free end of the loose reed was to be glued to a cork, and the cork was to be glued to the centre of a stretched membrane, in the manner I had been accustomed to fasten the lever of the phonograph with which I had been experimenting. In pursuance of these instructions, Mr. Watson immediately began to construct a membrane telephone; but when it was completed, I found that the armature he had arranged, in place of being one of the steel reeds I had intended, was a thick armature of soft iron, somewhat like the armature of a Morse sounder. This was pivoted at one end to the uncovered pole of the electro-magnet, and the other end was attached to the centre of a stretched membrane, but I do not quite remember the mode of attachment. I think a cork was employed at first, which was glued to the membrane. At all events, I do remember that we had great trouble with the apparatus. The moment a battery current was passed through the coil of the electro-magnet, the armature was so powerfully attracted as to pull the cork off the membrane; and when we had remedied this, the membrane itself would be ruptured. I do not now remember whether any practical experiments were made to transmit the voice with the apparatus thus constructed with a heavy armature, but I think not. I came to the conclusion that the armature was too heavy, and the membrane used too light, and

therefore gave instructions to have the instrument remodelled, with a lighter armature and a stouter membrane.

Int. 73. I show you a letter dated June 28, 1875, addressed to Gardiner G. Hubbard, Esq. Did you write it and send it to Mr. Hubbard on that date, and if so, will you read it as part of your answer?

Ans. I wrote it on the twenty-eighth day of June, 1875, and sent it to Mr. Hubbard. The letter is as follows:

SALEM, MASS., June 28, 1875.

DEAR MR. HUBBARD:

Mr. Hutchins (the organ builder) kindly devoted the whole of this afternoon to the construction of a steel reed for me.

One of the latest Receiving Instruments was inclosed in a wooden box and had its armature so arranged as to be set in vibration by a current of air passed through the box. The instrument was completed this evening in time for trial. Mr. Hutchins operated the Reed in the little room upstairs (Williams's office), while I observed the effect upon a Receiving Instrument placed in the basement of the building. The sound was so perceptible that I found it unnecessary to place my ear against the instrument. The vibration of the armature could also be seen and felt.

No battery nor permanent magnet was used.

I feel sure that a study of Ladd's or Wilde's Magneto-Electric Machine will reveal a means of increasing the intensity of the induced currents. I am told that Prof. Lovering has one of Wilde's Instruments in his possession, so I shall call upon him tomorrow for information concerning it.

Prof. Pickering has left town for the summer. I propose having the steel reed still further altered tomorrow, so shall probably be at the organ factory (Hutchins, Plaisted & Co., Cambridge Street, near Charles Street) most of the afternoon instead of at Williams's. Shall call in the evening and report progress.

Yours respectfully,

A. GRAHAM BELL.

GARDINER G. HUBBARD, Esq.,
Brattle Street, Cambridge.

P. S. The experiment referred to above was repeated when a single cell of a battery had been placed in the circuit. The amplitude of vibration of the armature downstairs was quite large enough to work the vibratory circuit-breaker. We were unable to try higher battery power on account of the sticking of the generating armature. When the instrument is altered tomorrow, I shall try higher battery-power and test the resistance through which the current will pass.

A. G. B.

Int. 74. Had you, before writing that letter, performed the experiments therein described, with the results therein stated?

Ans. I had.

Int. 75. You said in that letter that "No battery nor permanent magnet was used." By what means was the electric current generated, in the particular experiment so referred to?

Ans. I believed at the time that magneto-electric currents were generated by the vibration of the armature on account of residual magnetism in the core and armature of the electro-magnet, due to the passage of battery currents through the coil in previous experiments.

Int. 76. Before you caused a second membrane telephone to be constructed, did you, in the interval between June 2, 1875, and that time, conduct any other experiments than those you have mentioned, in which electric currents were generated by the vibration of an inducing reed in front of an electro-magnet, and if so, to what extent, and for what purpose?

Ans. I made a great many experiments in order to ascertain what arrangement of coils, etc., would produce the most powerful effects. For example, I remember having a double-pole electro-magnet with coils upon both legs, and a steel reed clamped firmly to one of the poles, with the free end overhanging the other pole. The reed of this instrument would be plucked by the finger, and the effect observed by pressing the ear against the reed armature of another instrument. A series of experiments would then be made, like the following: One of the coils of the transmitting instrument alone would be connected in circuit with the receiving instrument, and the effect noted when the reed was plucked. Then the other coil would be used alone, and the effect noted comparatively with the first. Then both coils would be used. Similar experiments would be made with and without a battery upon the circuit, and then again the experiments repeated with artificial resistances in the circuit, to make the conditions approximate to those upon a real line wire. The object of the experiments was to ascertain the best arrangement of the parts for producing a powerful effect upon a real line; and I proposed to apply the results in the construction of the membrane speaking telephone. Numerous other experiments were made, with

a similar object in view, in which the generator employed was not one of the steel reeds, but the permanent magnet to which I have before alluded, which was set in vibration like a tuning-fork, producing a musical tone. One of the prongs of this permanently magnetized tuning-fork would be held near the pole of an electro-magnet, and the audible effect produced was observed by holding one of the tuned-reed receivers to the ear. Variations in the arrangement of circuit were made, as in the case noted above, and comparative observations made to ascertain what arrangement would produce, with a given vibration at the transmitting end, the loudest audible effect at the receiving end. The results were to be applied in the construction of the membrane speaking telephone.

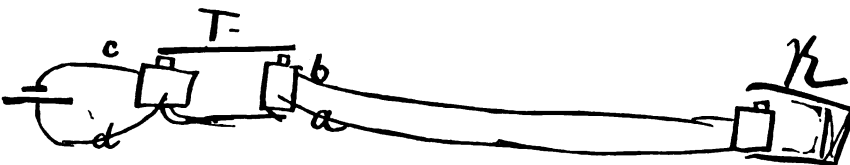
Int. 77. Will you describe a little more in detail the double-pole electro-magnet having coils upon both legs, and a steel reed clamped firmly to one of the poles, with the free end overhanging the other pole, referred to in the last preceding answer; and state what the arrangement was when a battery was used with the coil on the leg to which the steel reed was clamped. In this connection, also state what memorandum, if any, exists to corroborate your memory of the apparatus.

Ans. This apparatus consisted of a double-pole electro-magnetic core, to one pole of which one end of a steel reed was firmly clamped, the other end of the reed being free and coming very near to, but not touching, the other pole. On each of the legs of this electro-magnet was a coil of insulated copper wire, separate and independent from the other, so that one of the coils could be placed in the circuit without the other, or both could be used together, or one could be placed in one circuit and the other in another. One of the experiments made with a battery current passing through the coil surrounding that pole of the electro-magnet to which the reed was clamped was as follows: The other coil, that is, the coil on the end of the magnet under the free end of the reed, was connected in metallic circuit with a tuned-reed receiver, the armature of which was placed against the ear. From numerous experiments that had been previously made, I knew that under such circumstances the mechanical vibration of the transmitting reed acting on the residual magnetism in the core and armature would cause a magneto current to appear upon

the circuit, and produce an audible sound from the receiver; and I sought by experiments to ascertain whether an increase in the magnetic condition of the iron core and armature would yield improved effects. Hence, I connected that coil which surrounded the leg of the magnet to which the reed was clamped, in a local circuit with a battery, the other coil being in a separate and distinct circuit with the receiving instrument, without any battery. The function of the local battery and circuit was simply to cause a more powerful magnetic condition in the core of the electro-magnet and in the reed armature, and thus produce a condition analogous to that of a permanent magnet, but much stronger.

I have before me a memorandum of experiments made on June 30, 1875. It was introduced in evidence in the case of the *American Bell Telephone Company v. People's Telephone Company*. One of the diagrams, marked 3,* exhibits the experiment narrated. In the apparatus used, the two iron cores of the electro-magnet were magnetically connected by an iron back-piece or heel-piece, which was in contact with both legs.

Int. 78. From your description I understand that the transmitting instrument consisted, in effect, of two separate single-pole electro-magnets, having the bottom ends of their cores united by an iron heel-piece, and that the vibratory reed was clamped to the top of one of these poles so as to place its free end just above, but not touching, the top of the other pole. And I further understand that, in the particular experiment referred to, you put in circuit with a battery that coil which surrounded the core to which the vibratory reed was clamped, and put the other coil in circuit with one of your tuned-reed receivers without a battery. Is this understanding cor-



3. Battery connected with *cd* *T* plucked sound ~~the~~
sound similar to 2.

rect, and if so, will you further explain how the operation of the apparatus thus arranged was similar to that which would have resulted from the employment of a permanent magnet? In other words, what part of the apparatus performed the functions of the permanent magnet?

Ans. Your understanding of the arrangement is correct. I understood that when a battery current is passed through a coil surrounding a soft-iron core, the core becomes magnetic; that it is, in fact, to all intents and purposes, a permanent magnet, so long as the battery current passes. Now, in the arrangement referred to, the iron core within the coil through which the battery current passed was in magnetical contact at one end with the steel reed, and at the other with the heel-piece connecting it magnetically with the iron core of the other coil. Under these circumstances, I considered that all the connected pieces of iron and steel would become magnetical when the current was passed through the coil, just as a long, straight rod of iron would become magnetical if a small coil, having a battery current, surrounded its middle. Under such circumstances, the poles would be at the two extremities of the rod, and might be far outside the ends of the coil. I considered that the magnetic condition of the arrangement composed of the iron cores, heel-piece, and steel reed, would be somewhat similar to that of a long iron rod bent into that shape; so that when the battery current traversed the coil of the leg to which the reed was clamped, the poles of the magnet thus produced would be the free end of the reed, and the iron core underneath it. Under these circumstances, the vibration of the reed would be equivalent to vibrating one pole of a permanent magnet in the neighborhood of the other, and the coil connected with the distant receiver would be surrounding the fixed pole.

Int. 79. I have here a letter, dated July 1, 1875, and addressed to Gardiner G. Hubbard, Esq. Did you write it and send it to him on that date, and if so, please read it as a part of your answer.

Ans. I did. The letter is as follows:

SALEM, MASS., July 1st, 1875.

DEAR MR. HUBBARD:

The experiment to which I alluded when I saw you last promises to be a grand success. On singing this afternoon in front of a

stretched membrane attached to the armature of an electro-magnet, the varying pitch of the voice was plainly perceptible at the other end of the line, no battery nor permanent magnet being employed. When the vibrations are received upon another stretched membrane in place of a steel spring, it is possible, nay, it is probable, that the "timbre" of the sound will be perceived. I hope to try the experiment tomorrow afternoon.

This morning in dipping into a French work upon Telegraphy, I came across a full description of the "*Typo-Télégraphe de M. Bonelli*" I find it to be *identical* with our autograph arrangement, save that five telegraph wires are required instead of one for transmission.

Bonelli gets over the difficulty of *prepared ink* by setting up his message in type. The brush of wires is passed over the raised surfaces of the letters, securing perfect contact at the proper places.

I have an engagement to meet Professor Lovering tomorrow morning at ten o'clock, and shall call upon you before returning to town.

With kind regards,

Yours respectfully,

A. GRAHAM BELL.

GARDINER G. HUBBARD, Esq.,
Brattle St., Cambridge.

Int. 80. Did you try the experiment as related in that letter, of singing in front of a stretched membrane attached to the armature of an electro-magnet?

Ans. I did.

Int. 81. You spoke therein of your expectation of trying on the following day an experiment with another stretched membrane instrument as a receiver. Was such an instrument constructed, and was the experiment referred to tried, shortly after July 1, 1875?

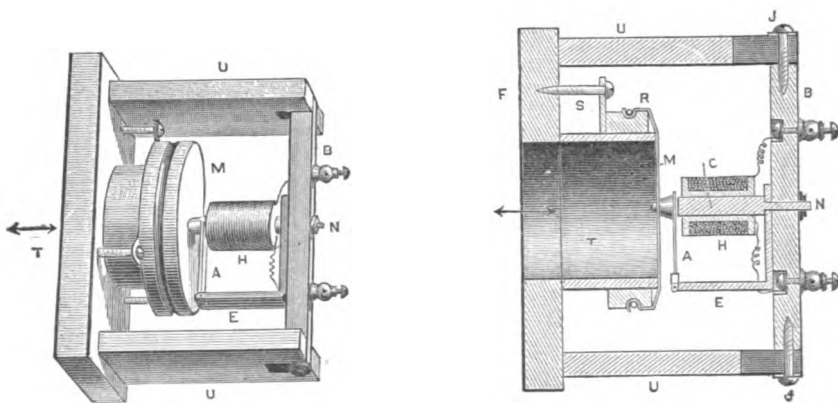
Ans. Yes.

Int. 82. Will you describe the instruments with which such experiment was tried, beginning with the one of earlier construction, and ending with that of later construction?

Ans. I have here some drawings, one showing the first instrument in perspective, and the other showing it in cross-section, by the aid of which I will make my description.

In this earlier arrangement, a membrane M is attached to a straining ring R, carrying three metallic projections, through which

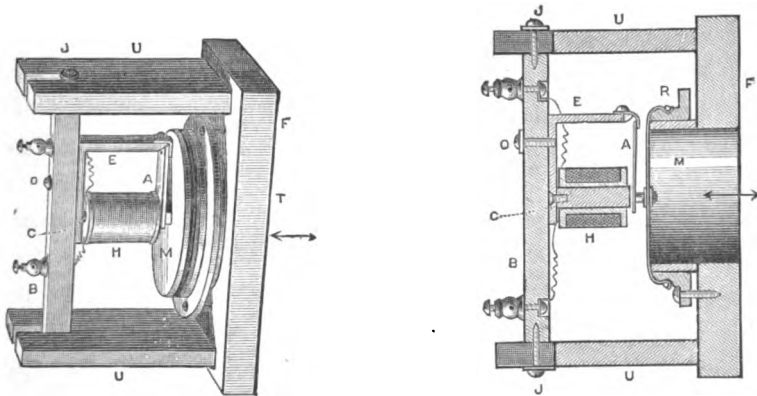
screws S pass into a board F. By the operation of screws S the membrane M can be stretched tightly across the end of a tube T.



Attached to the board F are side-pieces U, U, carrying a cross-bar B, which is retained in position in the slotted ends of the side-pieces by screws J, J. The cross-bar B supports an electro-magnet H, E, which is attached to the cross-bar by a screw and nut at N. The leg C of the electro-magnet is covered with a coil H of insulated copper wire, and to the uncovered leg E of the electro-magnet is pivoted one end of the steel armature A, the other end being attached to the centre of the strained membrane M. I am not sure, at the present moment, how the attachment of the membrane was made, but I think the drawing shows a piece of cork between the centre of the membrane and the end of the armature or reed. On the other side of the membrane is a metallic washer, through which passes a screw, clamping the membrane between the washer and the cork. I think this is the arrangement shown in the diagram. At all events, we used such an arrangement in some of our experiments in June or July, 1875. If I remember rightly, we did not at first adjust the electro-magnet, in the earlier instrument, by changing the position of the cross-bar; but we did so by means of the screw and nut shown at N. By unscrewing the nut a little, we could cause the electro-magnet to approach its armature more closely and retain this position by means of washers or thin pieces of metal placed between the cross-bar and the heel-piece of the electro-magnet. This was the first method, I think, of adjusting the position of the electro-magnet; and then came the plan

of fixing it firmly to the cross-bar, and adjusting the position of the cross-bar by the screws J, J. It may be perfectly possible that the cross-bar means of adjustment existed in the apparatus before the experiment was made, described in the letter of July 1. I cannot be sure now at this date.

I will now describe the second instrument, and will do so by the aid of the following drawings :



Comparing these drawings with the drawings of the earlier instrument given above, like parts are indicated by the same letters. I will simply point out the differences. In the second instrument, the straining ring R carried a circular flange, through which three screws passed, adjusting its distance from the board F. The tube T was much shorter than in the earlier instrument, so that the flange of the straining ring R came much closer to the board F. The electro-magnet H, E was attached firmly to the cross-bar B by a screw passing through a washer at O, and the distance of the pole of the electro magnet from its armature A was regulated by adjusting the position of the cross-bar B by means of the screws J, J. The steel-spring armature A was attached to the uncovered pole E of the electro-magnet by means of a leather hinge, and the end of the pole itself was filed to an edge which was intended to be in contact with the end of the armature A. The other end of the armature A carried a metallic pin, and a screw passing through the centre of the membrane into the metallic pin clamped the membrane firmly between two metallic washers.

Int. 83. Are the drawings to which you have referred in the last preceding answer made to scale, and if so, how do they compare in size with the original instruments?

Ans. The sectional drawings are made to scale, and are one fourth size.

Int. 84. Please, now, describe the trial which you made of these two instruments which you have described in your answer to Interrogatory 82, and state the results which you obtained from such trial, early in July, 1875.

Ans. One of these instruments was placed in a room in the upper part of Mr. Williams's building, 109 Court Street, Boston, and the other in one of the work-rooms below. The two instruments were connected together in metallic circuit, but I do not remember at the present moment whether a battery was used in the first experiment, or not. I spoke and shouted and sang — with my mouth as close to the membrane as possible — into the instrument upstairs, while Mr. Watson listened to the instrument downstairs. I remember that while I was talking or singing to the instrument upstairs, I was interrupted by the sudden appearance of Mr. Watson, who had rushed upstairs in great excitement, to tell me what he had observed below. I remember that he told me he could hear my voice quite plainly, and could almost make out what I said. I then asked Mr. Watson to do the speaking, but was myself unable to verify his assertion. We made a number of experiments at the time, changing places so that one should be upstairs and the other down. I do not remember the details of these experiments, nor exactly the results obtained, excepting that speech sounds were unmistakably produced from the receiver, and were almost intelligible, and that Mr. Watson appeared to hear a good deal more than I was able to do. While I am free to say that the character of the articulation produced was rather disappointing, the fact that any sound at all was audible, under the circumstances of the experiment, convinced me that the supposed difficulty which had been in my mind since the summer of 1874 — namely, that magneto-electric impulses generated by the action of the voice would be too feeble to produce distinctly audible effects — was a mistake, and the results encouraged me to believe that the apparatus, if carefully constructed,

and tried in a quiet place, would transmit speech intelligibly, and prove to be a practically operative speaking telephone.

Int. 85. Was Mr. Williams's building, where you carried on your electrical experiments, in the summer of 1875, a suitable place for the trial of the membrane telephones which you have described and referred to?

Ans. No. It was a very noisy place.

Int. 86. Did you subsequently make trial of just such instruments as your two membrane telephones which you have described in answer to Interrogatory 82, in a more quiet place, and compare the results obtained, with their trial in the same situation as when the originals were first tried; and if so, when, and what did you find their capacity to be?

Ans. Yes. I made experiments with membrane telephones that were substantially reproductions of the instruments used in the summer of 1875. I am not sure about the date, but think it may have been about 1879. The instruments were tried in Mr. Williams's establishment in about the same places occupied by the original instruments in 1875. I think it was Mr. Watson who made the experiments with me, but cannot be quite sure. I remember that, under such circumstances, I could hear the sound of the voice, but could not make out the articulation. The instruments were then carried off to some quiet place—and here again my memory fails me. I am inclined to think that they were taken either to some office on State Street, or some place on Milk Street; but at all events, I remember that it was some place of a quiet character, where there was no noisy machinery at work to distract the attention. The instruments were set up just as they had been immediately before at Mr. Williams's establishment, and I was able to carry on a conversation with the person at the other end,—at least, that is my recollection. I am perfectly sure of so much—that I heard and understood speech through the instruments in this quiet place, where I could not understand anything in the noisy workshop of Mr. Williams. I remember, also—during the course of the experiments in the quiet place, a fire-alarm struck, or some noise occurred outside, in which there was ringing of bells, etc., and that while the noise

lasted I could not make out what was said by the telephone, but when the noise ceased, I was able to understand again.

Int. 87. In what position were the membrane telephone instruments, described in your answer to Interrogatory 82, intended to be held when used; and how did you, in fact, hold them and their duplicates, when subsequently tried, when experimenting with them?

Ans. The position in which the membrane telephones were held was not material. In the experiments referred to I took the telephone up in my hand, and simply tried to get my mouth or ear, as the case might be, as close to the membrane as possible. In doing this I do not think I held the instrument in any uniform position, for I feel sure that I spoke with my mouth sometimes on one side of the membrane, and sometimes on the other, and listened in the same way. At all events, the position was immaterial.

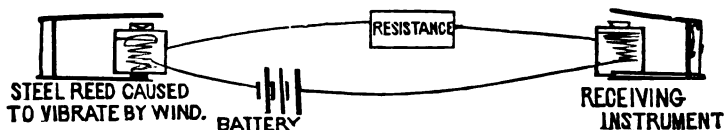
Int. 88. I show you a letter dated July 7, 1875, and addressed to Gardiner G. Hubbard, Esq. Did you write it and send it to Mr. Hubbard on that day? If so, please read it as part of your present answer.

Ans. I did. The letter is as follows:

SALEM, MASS., Wednesday, July 7th, 1875.

DEAR MR. HUBBARD:

I forgot to mention this evening the gratifying results obtained with the steel reed.



When three cells of a battery were introduced into the circuit (as shown in the figure), the armature of the Receiving Instrument vibrated with considerable amplitude. When a damper was adjusted for it to strike against, the sound could be heard at a distance from the instrument.

The helix at Transmitting end had a resistance of about two ohms, and yet the vibration of the armature of the Receiving Instrument could be detected when a resistance of 100 ohms was introduced into the circuit. This seems to me to indicate more power than can

possibly be due to magneto-electric currents generated by the vibration of the reed.

May not a pulsatory action be induced in *the voltaic current itself* by the motion of the reed? I can imagine the current alternately weakened and strengthened according to the distance of the armature from the pole underneath.

In this case the pulsations would certainly be available for our purpose, by merely increasing the battery power sufficiently to overcome the resistance of the Line. Magneto-electric currents are, however, evidently present, for a sound is perceptible at the receiving end when the battery is omitted altogether.

I think, also, that the effects are in some way dependent upon the peculiar form of electro-magnet employed. I hope to get some light on the subject from Moncel. He devoted several pages to the discussion of peculiarities observed in the one-legged or "*lame*" magnet (*boîteux*), shown in his work as follows:



He says, "Ce genre d'électro-aimant, que j'ai beaucoup étudié et le premier employé dans les applications électriques, a beaucoup d'avantages dont nous parlerons plus tard, et *une force beaucoup plus considérable qu'on ne semblerait le croire à première vue*" . . .

With kind regards, yours Respectfully,

A. GRAHAM BELL.

GARDINER G. HUBBARD, Esq.,
Brattle Street, Cambridge.

Int. 89. I show you another letter, dated August 14, 1875, and addressed to Gardiner G. Hubbard, Esq. Did you write it and send it to Mr. Hubbard on the date which it bears, and if so, will you read it as part of your present answer?

Ans. I did. The letter is as follows:

SALEM, MASS., August 14th, 1875.

DEAR MR. HUBBARD:

On glancing back over the line of electrical experiments, I recognize that the discovery of the magneto-electric current generated by the vibration of the armature of an electro-magnet in front of one of the poles is the most important point yet reached. I believe that it is the key to still greater things.

The effects produced, though slight in themselves, appear to me so

great in proportion to their cause that I feel sure that the future will discover means of utilizing currents obtained in this way on actual telegraph lines.

So important does it seem to me to protect the idea that I think some steps should be taken immediately towards obtaining a Caveat or Patent for the use of a Magneto-Electric Current, whether obtained in the way stated above, (by the vibration of permanent magnets in front of electro-magnets,) or in any other way. I should wish to protect it specially as a means of transmitting simultaneously musical notes differing in *intensity* as well as in pitch.

I can see clearly that the magneto-electric current will not only permit of the actual copying of *spoken utterance*, but of the simultaneous transmission of *any* number of musical notes (hence messages) without confusion.

The more I think of it the more I see that the method of making and breaking contact so many times per second is only the *first stage* in the development of the idea.

When we can create a pulsatory action of the current which is the *exact equivalent* of the aerial impulses, we shall certainly obtain exactly similar results. *Any number of sounds* can travel through the same air without confusion, and any number should pass along the same wire.

It should even be possible for a number of spoken messages to traverse the same circuit simultaneously, for an attentive ear can distinguish one voice from another, although a number are speaking together.

Don't you think it would be well to take out a *caveat* for the use of the magneto-electric current?

In its present undeveloped state, it might be unwise to let Gray know anything about it unless indeed we could secure the *principle* of it in a patent.

Yours respectfully,

A. GRAHAM BELL.

GARDINER G. HUBBARD, Esq.,
Cambridge.

Int. 90. What were your occupations and your state of health between the early part of July, 1875, and the time when you made your usual summer visit to the home of your parents, in Canada?

Ans. If I recollect rightly, in July, 1875, I was in very poor health, and I occupied a portion of my time in Salem in the instruction of my little deaf pupil, George Sanders, and went into Boston when I felt well enough, for the purpose of experimenting at Mr. Williams's establishment. I remember that for some time before I wrote the letter of August 14, 1875, which I have given above, I

was able to carry on few, if any, experiments, and occupied my spare time chiefly with thinking over the results of the experiments I had made, and trying to decide what I should do. On the 14th of August I wrote to Mr. Hubbard, summing up these deliberations. I have a recollection that experiments in Boston were also interfered with by some illness of Mr. Watson at that time. As he was the workman especially assigned by Mr. Williams to make my apparatus, and was the only man I could trust to help me in my experiments—he knowing confidentially about them, and the other workmen having no such knowledge—experiments were necessarily interrupted, quite independently of my health, and I was thrown back upon theoretical work, my deliberations resulting in the letter of August 14 to Mr. Hubbard. During August my health became quite seriously impaired, and at last I went to the home of my parents, in Canada, to recruit.

Int. 91. I show you a letter dated September 28, 1875. Did you write it and send it to Mr. Gardiner G. Hubbard on that date, and if so, where were you when the letter was written?

Ans. I did write it and send it to Mr. Hubbard, September 28, 1875. At that time I was in Toronto, Canada.

Int. 92. How far was Toronto from Brantford, where your parents resided?

Ans. I cannot state with any accuracy. I should say from 75 to 80 miles. There was railroad communication between Brantford and Toronto.

Int. 93. Please read as a part of your present answer such parts of this letter of September 28, 1875, as relate to your electrical inventions.

Ans. I read as follows:—

IMPERIAL BANK OF CANADA.

TORONTO, Sept. 28, 1875.

DEAR MR. HUBBARD:

You must not think that I have been neglecting telegraphy during my visit to Canada. I brought a couple of instruments with me, and have discovered a method of annihilating the spark that has caused me so much trouble, without the necessity of using a condenser. I have felt very anxious in the matter of foreign patents, and, as I have not heard anything from the friends on the other side

to whom I applied for assistance in the matter, I thought I would see friends in Toronto and Montreal. My idea was to get a letter of introduction to Sir Hugh Allan, and seek his aid in the matter. On consulting my friend, Honorable George Brown (Ex-Premier of Canada), he became much interested, and offers, if the scheme seems likely to be a good thing, either to take up the matter himself or get two or three gentlemen to do so. I have arranged to write particulars at once to him in confidence, and if we come to an arrangement they will telegraph to England to set matters afoot there and on the continent at once. I must be in Belleville tomorrow, but shall not delay in Montreal to see Sir Hugh. . .

I shall try to see you as soon as possible. I cannot reach Boston before Friday or Saturday.

With kind regards,

Yours respectfully.

A. GRAHAM BELL.

Int. 94. When and where did you begin to prepare the specification for the application which resulted in the issue of patent No. 174,465, of March 7, 1876?

Ans. I commenced writing the specification in Canada, at my father's house, in September, 1875.

Int. 95. I show you seven sheets, foolscap size, upon which appears writing, in pencil and in ink. In whose handwriting is what is written thereon; what is the principal subject-matter; and if they were noticed in your former testimony, when first?

Ans. The handwriting on these sheets is my own. The sheets constitute fragmentary remains of rough drafts of the specification for my patent of March 7, 1876. They were referred to in my testimony in the *Dowd* suit, and from the examiner's notes upon them, they were produced in that suit on July 10, 1879.

Int. 96. Please read from these sheets such passages as I will point out to you.

Ans. I read from sheet 1 :

"My present invention consists in the employment of a vibratory or undulatory current of electricity in place of a merely intermittent one, and of a method of and apparatus for producing electrical undulations upon the line wire"

Following this is the word "Phono-Telegraphy." The foregoing is written in pencil.

On the opposite side of the same sheet, the page begins :

"by inducing undulations in (upon) a continuous voltaic circuit by the motion of bodies capable of affecting the current, such as the armature of an electro-magnet, a permanent magnet, or a body through which a continuous current of electricity is passed."

This is accompanied by a drawing, substantially like A, Fig. 5 of my patent of March 7, 1876. The paragraph and the drawing are in ink.

I read from sheet 2 :

"It has long been known that when a permanent magnet is caused to approach the pole of an electro-magnet, a current of electricity is induced in the coils of the latter, and that when it is made to recede a current of electricity of opposite polarity to the first appears upon the wire. When, therefore, a permanent magnet is caused to *vibrate* in front of the pole of an electro-magnet, an undulatory current of electricity is induced in the coils of the electro-magnet, the undulations of which correspond in number per second to the vibrations of the magnet — in polarity to the direction of motion of the permanent magnet — and in intensity to the amplitude of the vibration of the permanent magnet."

The portion just read is written in pencil.

On the same page of the same sheet there is also written in pencil the following :

"CLAIMS.

1. In a system of telegraphy in which the receiver is set in vibration by the action of the electrical current, the employment of vibratory or undulatory currents of electricity as distinct from merely intermittent currents.

2. The method of inducing (impressing) undulations in a continuous voltaic current by the vibration or motion of bodies capable of affecting the current, whether such bodies be permanent magnets, the armatures of electro-magnets, or bodies through which a continuous current of electricity is passing.

3. The Phono-Telegraph whereby two or more vocal or other sounds, differing in pitch, loudness and timbre, can be transmitted singly or simultaneously along a single wire, by causing electrical undulations upon the wire, similar in *form* to the aerial vibrations accompanying said vocal or other sounds."

On the other side of sheet 2 is the following, written in ink :

"In illustration of the method of creating a vibrat. current of elect., I shall show and describe one form of apparatus designed to produce undulations in a continuous voltaic current. But I wish to state here that the same effect may be produced in many other ways,

all that is necessary being to influence the current by the vibration or motion of bodies capable of affecting the current."

From sheet 3 I read the following, in pencil :

"4. The method of producing an undulatory current by the vibration of a body through which a continuous current of elect. is passed."

"6. The method of and apparatus for transmitting simultaneously sounds differing in 'timbre' as well as in pitch and in loudness.

7. The method of and apparatus for transmitting vocal utterance telegraphically, substantially as herein set forth."

On sheet 4 is the following, written in ink :

" CLAIMS.

"1. In a system of telegraphy in which the receiver is set in vibration by the passage of the electrical current, the employment of vibratory or undulatory currents of electricity as distinct from merely intermittent currents.

2. The method of impressing (inducing) undulations upon a continuous voltaic current by the vibration or motion of bodies capable of affecting the current, whether such bodies be permanent magnets, armatures of electro-magnets, or bodies through which a continuous current of electricity is passing.

3. The Phono-Telegraph whereby the exact pitch, loudness and *timbre* of vocal or other sounds can be transmitted telegraphically, by causing the body, by whose motion undulations are induced upon the line wire, to copy exactly the aerial vibrations accompanying said vocal or other sounds, and hence to induce upon the line wire, electrical undulations similar in *form* to those occurring in the air."

On the other side of the same sheet the page begins with the following incomplete sentence, written in pencil :

"In another application for letters patent I have described a method of and apparatus for transmitting two or more telegraphic"—

Int. 97. On that side of sheet 4 from which you have just read the incomplete sentence, written in pencil, appears some writing in ink, the last few words of which are written over a few words of the pencil writing. What is that which is written in ink?

Ans. It is a portion of a rough draft of a letter that I wrote to James J. Barclay, secretary of the Board of Directors of the Pennsylvania Institution for the Deaf and Dumb, giving my terms for introducing my father's system of Visible Speech into the Philadelphia institution, and devoting two months to the instruction of the

teachers and pupils. The date of this letter I can fix approximately by means of another letter of mine to Mr. Barclay, dated November 13, 1875, the original of which I hold in my hand. This letter commences as follows :

“ MY DEAR SIR :

“ Many thanks for your kind note of the 4th inst. I am sorry that the Institution cannot consider my terms,” etc.

The letter of November 4, 1875, to which reference is made, was a reply to my letter to Mr. Barclay giving my terms, a portion of the rough draft of which appears on the back of sheet 4. The rough draft was, therefore, written before the 4th of November 1875. It commences with the following words :

“ I have delayed answering your note of the 22d inst.,” etc.

The rough draft was, therefore, undoubtedly written in the month of October, after the 22d of that month.

Int. 98. Are these seven sheets all the original rough drafts which you made in preparation of your specification for the application which resulted in the issue of your patent of March 7, 1876?

Ans. By no manner of means. I wrote and rewrote the specification a great many times, and these sheets are mere fragmentary remains which happened to be accidentally preserved.

Int. 99. When were you chiefly occupied in preparing your draft of that specification?

Ans. In the early part of October, 1875, immediately upon my return from Canada.

Int. 100. Do you remember the date when you made oath to the completed specification, and executed your application which resulted in the issue of your patent of March 7, 1876, and the place where you so executed it?

Ans. I made oath to it on the 20th of January, 1876, in Boston.

Int. 101. From whom did you receive the fair copy of the application which you so executed, and how did it reach you?

Ans. From Messrs. Pollok & Bailey, my solicitors in Washington. I hold in my hand what I am informed and believe is a press copy of the letter from Mr. Pollok enclosing the specification and oath for my signature, which is as follows :

JAN'Y 18, 1876.

Mr. A. GRAHAM BELL :

Dear Sir, — Herewith find applic., papers, etc., for your new improvements in telegraphy. We have left blank for title of invention in the Oath, which you can fill in.

Please execute the papers as indicated in pencil, and return them to me.

Very truly yrs.

The application papers reached me by mail in due course, and were sworn to on the 20th of January, and returned to Washington.

Int. 102. It appears in evidence that this application was filed February 14, 1876. Will you state briefly why it was not sooner executed and filed?

Ans. I was anxious to have patents taken out for the same invention in foreign countries, as well as in the United States. In September, 1875, I had arrived at an understanding with the Hon. George Brown, of Toronto, and his brother, Mr. Gordon Brown, that they would take out patents for me in foreign countries. But they desired that the specification upon which I was then at work should not be filed in the United States Patent Office until they had had time to make arrangements for taking out the patents simultaneously in Europe. I therefore left them, at the end of September, 1875, with the understanding that I should immediately complete the new specification and send them a copy, and not do anything in the United States Patent Office that could conflict with their interest abroad until I heard from them. This was a mere verbal understanding, but the Hon. George Brown stated that he would write to me as soon as possible, and make a definite agreement in black and white. I returned to Boston about the first of October, 1875, and while waiting for the promised communication from the Hon. George Brown, I occupied myself with completing the specification, so as to be ready to send him a copy the moment a definite agreement had been arrived at. I wrote and rewrote the specification several times during the early part of October, 1875, and certainly by the middle of October it was substantially completed. The promised communication from the Hon. George Brown, however, did not come. As time went on, I was repeatedly urged by my associates, Mr. Hubbard and Mr. Sanders, to file the specifica-

tion in the United States Patent Office, but I hesitated to do so at the risk of destroying all chance of obtaining foreign patents. Mr. Hubbard was especially anxious about the matter, but I pleaded with him to let the matter lie in abeyance until after my Christmas holidays, so that I might have one more chance to complete arrangements with the Browns. I agreed that if I could not, during these Christmas holidays, make definite arrangements for foreign patents, then the specification might be filed in the American Patent Office, without reference to other countries. During the Christmas vacation, 1875, I visited Toronto, and finally, on the twenty-ninth day of December, 1875, a written agreement was definitely concluded between the Browns and myself, and I promised to place in Mr. Brown's hands copies of my specifications. I cannot now remember whether I had or had not with me in Toronto, on the twenty-ninth day of December, 1875, a copy of the specification of my patent of March 7, 1876, but I do remember that on that occasion I handed to him some papers, and promised to send the remainder by mail as soon as I could have them prepared. Immediately upon my return to Boston, about the new year, I set to work, with the assistance of friends, making copies of my different specifications to be forwarded to him. My recollection is that I did forward to him, within a few days after the first of January, 1876, quite a number of papers containing copies of specifications. I do not now recollect whether the specification of the patent of March 7, 1876, was among those sent to him in the early part of January, 1876, or among the papers given to him on the twenty-ninth day of December, 1875, or whether this specification was subsequently given to him when I saw him in New York on the 25th of January, 1876, just before he sailed to Europe. But at all events, it was given to him with the express understanding that it should not be filed in the United States Patent Office until a cablegram could be received from him, so that no action should be taken in the United States that would prove prejudicial to his interests abroad. The American application was sworn to in Boston, on the 20th of January, 1876, and was sent to Washington and placed in the hands of my solicitors there, ready to be filed the moment word should be received from the Hon. George Brown that we might go ahead without interfering with his

interests. Mr. Brown neglected to take any action in the matter, and sent no cablegram; and Mr. Hubbard, becoming impatient at the delay, privately instructed my solicitors to file the specification in the American Patent Office, and on the fourteenth day of February, 1876, it was so filed without my knowledge or consent.

Int. 103. You have given a history of the development of your invention of the method by which vocal and other sounds, including articulate speech, could be transmitted and reproduced electrically, and of magneto-electric apparatus employing such method. In the specification of your patent of March 7, 1876, other means of employing the same method are specified, operating by varying the external resistance of the circuit. Will you explain the antecedents out of which was developed your invention of the variable-resistance mode of employing your method of creating electrical undulations similar in form to the aerial vibrations accompanying the vocal or other sounds to be transmitted and reproduced.

Ans. I have already stated that magneto-electric apparatus for this purpose was devised by me in the summer of 1874, and that, for a long time, I was impressed by the idea that electrical impulses generated by the voice itself, or by the vibration of a permanent magnet or permanently-magnetized reed in front of the pole of an electro-magnet would be too feeble for practical use upon real lines. For many months the problem was in my mind how to increase the strength of a current moulded into undulations in this way. I saw that what I wanted was a current that varied in intensity as the air varied in density during the production of a sound, and it occurred to me that the intensity of a current was dependent upon two elements: 1, the electro-motive force employed; and 2, the resistance of the circuit; and that a variation of either of these elements would necessarily produce a corresponding variation in the intensity of the current. It therefore occurred to me that if I could cause the resistance of a voltaic circuit to vary as the air varied in density during the production of a sound, similar variations in the intensity should be produced. Only, in this case, the electro-motive force, being constant, might be made as great as we liked; and thus, by employing a battery of sufficient power, the apparatus might be made operative upon real lines. The more I thought of this, the more I

was impressed with the idea. But it was a little more difficult matter to devise a practical means of causing the resistance of a circuit to be varied in the manner desired. But in the spring of the year 1875, I devised a method that seemed worthy of trial, which was communicated to Mr. Hubbard in a letter dated May 4, 1875, which has already been quoted in my testimony in answer to Interrogatory 59. This method proposed to take advantage of the fact that the resistance offered by a wire to the passage of an electrical current is affected by the tension of the wire; so that if a continuous current of electricity were passed through a vibrating wire, it should meet with a varying resistance corresponding to the vibrations of the wire.

In my letter of May 4, 1875, I say :

“The plan for transmitting *timbre* that I explained to you before — viz., causing permanent magnets to *vibrate* in front of electro-magnets — is chiefly defective on account of the feebleness of the induced currents.

If the other plan is successful, the strength of the current can be increased *ad libitum*, without destroying the *relative intensities of the vibrations*.”

This variable-resistance mode of producing electrical undulations for the purposes of my invention remained in my mind for a long period of time as a theoretical alternative for the magneto-electric mode; but I was not thoroughly satisfied with the means of varying the resistance suggested in my letter of May 4, 1875. I had been unable to test the proposed experiment properly, on account of the construction of the pianos alluded to in the letter, and the production of a variable resistance by the vibration of a wire through which a continuous current was passed was recognized by me as a possible means, which had not been reduced to actual experiment.

In September, 1875, I carried on experiments at my father's house, in Canada, with circuit-interrupting transmitters and tuned receivers. In reference to these experiments, I wrote to Mr. Hubbard from Toronto, on the 28th of September, 1875, in a letter which has been quoted in my answer to Interrogatory 93, as follows :

“DEAR MR. HUBBARD :

You must not think that I have been neglecting telegraphy during my visit to Canada. I brought a couple of instruments with me, and

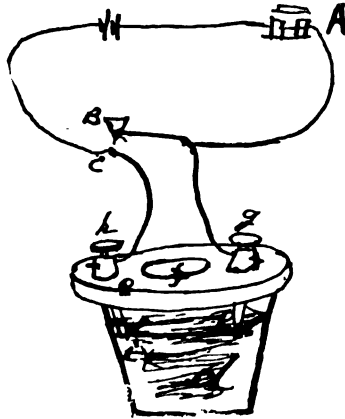
have discovered a method of annihilating the spark that has caused me so much trouble, without the necessity of using a condenser."

The method referred to consisted in the employment of water as a circuit for the induced current that occasioned the spark. At the moment the transmitting reed broke the circuit, the action of the current upon itself, in the coils of the electro-magnet employed occasioned an induced current of such strength as to leap across the gap in the circuit, creating a brilliant spark which would cause oxidization of the contact-points and thus interfere with the proper action of the transmitter. Now, it occurred to me that if I could bridge across this gap with a substance of very high resistance, the voltaic current would be so much enfeebled when the contact points were separated, that practically the voltaic current would not appear upon the circuit at all. It was obvious to me that for the purposes of multiple telegraphy, the bridge or path between the contact-points should have as high a resistance as possible; for the greater the resistance, the more nearly would the current upon the circuit become a really intermittent one.

For the purpose, however, of affording a path for the induced current, the bridge or path between the contact-points should have as low a resistance as possible, in order to avoid heating effects. It appeared to me, therefore, that the exact amount of resistance to be placed in the gap between the two contact-points was a matter for experimental adjustment. What we wanted was the highest resistance possible that would prevent the production of the spark. The high-resistance bridge I used consisted of a vessel of water. A wire was brought from each of the contact-points between which the spark appeared, and the ends of the wires were placed in the water. In order to make the resistance of the water as great as possible, the wires, or one of them at least, was allowed to dip into the water as slightly as possible. If, under these circumstances, the spark still appeared, the wire was adjusted a little more deeply in the liquid, so as to cause a larger surface of the wire to come in contact with the water, and thus reduce the resistance of the water path. As I gradually lowered the wire in the water I would watch the contact-points. The spark would gradually become enfeebled, and when a certain depth of immersion was reached, it would disappear

altogether. I sought to adjust the apparatus so that the depth of immersion should be as slight as possible, consistent with the disappearance of the spark.

During the first week in January, 1876, I prepared a specification for a patent upon this spark-arrester. It was sent to the Hon. George Brown, and by him taken to England. This specification is still in existence, and I hold in my hand the original copy given to George Brown, with the original drawing made at the same time to illustrate the specification. This same specification was put in evidence in the case of *American Bell Telephone Co. v. People's Telephone Company*. I will read from this specification the description of the apparatus, and will here insert a copy of the drawing.



“When a Morse sounder (A) or other telegraphic or electrical apparatus is placed in a voltaic circuit, the induction of the current upon itself in the coils of the electro-magnet (A) or other instrument gives rise to an induced current of high tension.

When the circuit is broken at any point, as by the lifting of the key (B) the induced current leaps across the break (D C) in the circuit in the form of a bright spark. When a powerful battery is employed, or when the circuit is very rapidly made and broken the spark becomes so intense as to burn or oxidize the points (B C) between which it appears, and thus prevent the effective working of the instruments upon the circuit.

This defect has hitherto been overcome by the employment of *condensers* by means of which the spark has been materially lessened or destroyed.

Now, I have discovered that the same effect may be produced by

introducing between the points (B C) where the circuit is broken *an imperfect conductor of electricity* which shall offer a very great resistance to the voltaic current, but afford a free passage for the induced current which occasions the spark.

Such a substance is *water*, especially when slightly acidulated. Retort carbon, plumbago, animal and vegetable tissues, and other substances offering a high resistance answer the purpose; but I prefer to employ a liquid (like water) which can be decomposed by the passage of the current.

The form of spark-arrester which I have devised consists of a glass vessel (*d*) containing water which has been slightly acidulated. The cover (*e*) is formed of a non-conducting material (such as wood or hard rubber) and has a hole (*f*) in it to permit of the escape of the gases formed by the decomposition of the water. Two screws (*g h*) pass through the cover (*e*) into the water at (*k* and *i*), and can be lowered or raised so that a larger or smaller surface may be brought into contact with the water.

Connecting wires unite the screw cups (*g* and *h*) respectively with the points (B C) between which the spark appears.

When the key (B) is raised, the voltaic current meets with so much resistance from the water in *d* as to be unable to affect the Morse sounder A or other instrument upon the circuit — so that the circuit is practically broken at B C; and the induced current finding a freer passage through the water in *d* than across the space B C prefers the former and thus no spark appears between B and C."

During the early part of January, 1876, my time was fully occupied with the preparation of copies of various specifications for Mr. Brown, and in the final revision of the specification for the United States Patent Office, which ultimately became my patent of March 7, 1876. Almost at the last moment before sending this specification to Washington to be engrossed, I discovered that I had neglected to include in it the variable-resistance mode of producing electrical undulations, upon which I had been at work in the spring of 1875, and which I described to Mr. Hubbard in my letter of May 4 of that year. The efficiency of the means described in that letter was, however, still problematical, as the experiments had not been properly tried, and it occurred to me that the means adopted in my spark-arrester of varying a resistance by dipping a wire more or less deeply into water, so as to increase or diminish the extent of surface of the wire in contact with the water, would be eminently suitable as an illustration of the variable-resistance mode of producing undulations. The form that this idea took in my mind at the time was to cause a

break in the metallic portion of the circuit, and bridge over the break by a vessel of water, as in my spark-arrester. The wire on one side of the gap was to make contact with the water in any convenient or suitable manner, and the other wire was to be arranged vertically over the water, with the lower end dipping very slightly into the water, as in my spark-arrester; so that a slight vertical vibration of the wire should make a great difference in the extent of surface in contact with the water, and thus occasion considerable variations in the resistance of the circuit during the vibration of the wire. All that was necessary, it seemed to me, to illustrate this mode of producing electrical undulations, was to attach the wire I desired to vibrate to the various instrumentalities shown and described in my specification, and illustrated in Figs. 5 and 7. That is, the water would take the place of the electro-magnet in the transmitting instrument, and if it was desired to produce undulations for the purpose of multiple telegraphy, the wire that dipped into the water would be attached to the free end of the reed illustrated in Fig. 5; and if it was desired to transmit vocal or other sounds telegraphically — including articulate speech — the wire to be vibrated should be attached to the centre of the stretched membrane shown in Fig. 7, which would then have to be substantially horizontal, to admit of the vertical vibration of the wire. This application of the spark-arrester principle to the mode of producing electrical undulations by varying the resistance of the circuit occurred to me, as I have already said, while I was making the final revision of my specification for the United States Patent Office, and almost at the last moment before sending it off to Washington to be engrossed. I immediately tried to express the idea in a clause to be inserted into the specification, describing the variable-resistance mode. In this clause, I described various means that occurred to me, whereby the resistance could be affected in the manner desired, such as the reciprocal vibration of the elements of the battery to affect the internal resistance. When I came to describe the proposed mode of affecting the external resistance by the vibration of the conducting wire in water, it occurred to me that water was not a good illustrative substance to be specified in this connection, on account of its decomposibility by the action of the current. I therefore preferred to use as a typical example a

liquid that could not be decomposed by the current, and specified mercury as the best example of such a liquid known to me.

All the parts of the specification alluding to the variable-resistance mode of producing electrical undulations were put in by me at the very last moment, before sending the specification off to Washington to be engrossed. The specification was then engrossed in Washington, at the office of my solicitors, Messrs. Pollok & Bailey. A clean copy for my signature and oath was forwarded to me from Washington on the eighteenth day of January, 1876. It was received by me, in due course, and I signed and made oath to it in Boston, on the 20th of January, 1876. It was then returned to Washington, and was filed in the United States Patent Office on February 14, 1876.

I may add that, by some oversight, these variable-resistance clauses did not appear in the copy of the specification which was taken to England by George Brown. He had probably received his copy before the clauses had been written, and when I met him in New York, on the 25th of January, by some accident the matter was overlooked.

Int. 104. To what extent did you carry on electrical experiments between your return from Canada, about October 1, 1875, and the filing of your application February 14, 1876, for the patent which afterwards issued to you March 7, 1876; and if such experiments were few, what was the reason for your want of activity in that direction?

Ans. Very few experiments were made during the period mentioned. In order that the reason may be understood, I must direct attention to my pecuniary condition in the summer of 1875, when I went to the home of my parents, in Canada, to recruit my health. During the year 1875, I had devoted my time to my electrical researches, to the neglect of the professional work upon which I was dependent for support. My associates, Mr. Sanders and Mr. Hubbard, although they had agreed to pay the expenses of the construction of my experimental apparatus, had made no provision to pay me for my time. When my professional work had become disorganized, I could, of course, have made some arrangement for my support with Messrs. Sanders and Hubbard; but on account of the delicate relations that began to arise between myself and Mr.

Hubbard, I was unwilling to ask for any assistance, and did not even care that Mr. Hubbard should know of my pecuniary condition. The delicate relations to which I allude, will be understood when I say that Mr. Hubbard's daughter is now my wife. At the time I left for Canada, in the summer of 1875, my health had given out, and my professional work also, and during that summer vacation it became a matter for serious consideration what I should do in the future. I desired to place myself in such a position pecuniarily that I should be able to marry. On the one hand, I knew that if I devoted myself to my professional work, it was capable of yielding me an income; and on the other hand, I believed that if I devoted my attention exclusively to my electrical inventions, they would bring me in a fortune. I decided, therefore, that if I could make arrangements for my support, without the necessity of applying to Mr. Hubbard, I would throw up my professional work, and devote myself almost exclusively to my electrical researches.

In September, 1875, I thought I had arrived at an understanding with the Hon. George Brown and his brother which would enable me to do this, and when I arrived in Boston, about the first of October, 1875, I awaited with feverish anxiety the arrival of the expected agreement in black and white. In the meantime, I devoted myself to the completion of the specification that I believed would bring me fortune. It was soon substantially completed, but the expected agreement with the Messrs. Brown did not arrive, and I was left to my own resources. Without assistance of some sort it was impossible for me to give up my professional work, as I had already received payment for lectures at the Boston University that were yet to be given. I need hardly say, then, that the non-arrival of the expected communication from Canada placed me in a very serious predicament. I could not give up my professional work, and I was determined that I should carry on my electrical researches. At last I formulated a plan that I believed would enable me to carry out both objects. I thought that the quickest way of getting back to my electrical researches would be to devote my time for awhile almost exclusively to my professional work.

Great interest had been aroused by the successful results of my attempts to teach deaf-mutes to speak, and a demand had arisen in

institutions for the deaf and dumb for teachers who were acquainted with my methods. It occurred to me that if I were to lecture at different normal schools on the subject of teaching speech to the deaf, and let it be known that a demand for articulation-teachers had arisen, it might be possible for me to form a large class of students from the normal schools who might desire to qualify themselves as teachers of articulation. The fees from this class might be sufficient to enable me, by economy, to support myself alone; and after a short period of instruction, these normal students might be able to relieve me of the work of instructing private pupils. By handing over private pupils to the members of my normal class, I would be enabled to devote the time necessary for their instruction to my electrical work, and I would be holding my profession together, so that I should not be entirely dependent upon the success of my electrical experiments, but should have a profession to fall back upon in the event of non-success.

This plan I carried out in its entirety. About the latter part of October, 1875, I lectured at the normal schools, and as a result was enabled to form a large class of normal students. As my private pupils had given out, I was obliged to organize free classes of adult deaf-mutes, in order to afford practice to the normal students in my care. The attention I paid to my professional work soon began to show effects in the appearance of private pupils who were either deaf, or were hearing persons with defective speech. As the year advanced, my private pupils increased in numbers to such an extent that I had very little time for experimental work, and it was not until the commencement of the year 1876 that members of my normal class were sufficiently qualified to relieve me of this class of work. On the 29th of December, 1875, I concluded the agreement with the Hon. George Brown and his brother, but, as I had already made provision for my own support, I could not ask them for the pecuniary considerations which had been proposed the previous September. I asked them, however, to pay the expenses of special rooms where I could keep my electrical apparatus in a private manner, as I was quite troubled by rumors that had reached me that strangers were visiting Mr. Williams's workshop, and examining my apparatus with curious eyes. The Browns agreed to this, and

in January, 1876, on the strength of this agreement, rooms were engaged at No. 5 Exeter Place, Boston, to which my apparatus was removed. It was not, however, until February, 1876, that I was able to relieve myself, to any great extent, of the work of private instruction, by handing pupils over to the members of my normal class. In that month, however, I was enabled to do this, and I then devoted the time saved in this manner to experimental work.

Int. 105. You have said that your specification executed January 20, 1876, was filed February 14, 1876, without your knowledge or consent. When that fact came to your knowledge, was the prosecution of that application carried on with your consent and approval?

Ans. It was.

Int. 106. While that application was pending, did you visit Washington, and if so, when for the first time?

Ans. I did. I arrived in Washington for the first time on the morning of Saturday, February 26, 1876.

Int. 107. When was the *Harmonic Telegraph Interference* between your application of February 25, 1875, and the applications of Paul LaCour and Elisha Gray formally declared? In answering this question you may refer to the certified copy of the File-wrapper and Contents in the matter of your said application, which I hand you.

Ans. February 16, 1876.

Int. 108. It appears in evidence that on February 29, 1876, certain amendments to your specification which had been filed February 14, 1876, were filed on your behalf in the United States Patent Office. Will you state briefly under what circumstances these amendments were prepared and filed, and what participation, if any, you had in the matter?

Ans. My solicitors, Messrs. Pollok & Bailey, informed me that the Examiner was inclined to think that there was some interference between my specification filed February 14, 1876, and another specification of my own filed the year previously, on the 25th of February, 1875; and they recommended me to go and see the Examiner, and explain to him the exact points of difference between the two applications. In order that the point of difficulty may be understood, I shall quote from the application filed February 14, 1876, the fourth claim, as originally filed. It was as follows:

"4. The method of producing undulations in a continuous voltaic circuit by alternately increasing and diminishing the resistance of the circuit; or by alternately increasing and diminishing the power of the battery as set forth."

Now, in the body of my specification filed February 25, 1875, occurred this passage :

"I prefer to produce the intermittent current by actual make and break contact. But the result may be attained by alternately diminishing and increasing the intensity without absolute break in the continuity of the current."

My solicitors told me that the Examiner was a little inclined to think that I was claiming in my application of February 14, 1876, what I had already shown and described in my application of February 25, 1875, and they recommended me to see the Examiner, and explain to him exactly the points of difference. I did so, and at his request reduced my statement to writing in the form of an amendment to be inserted in the application filed February 14, 1876. I drew up this amendment myself, at the office of Messrs. Pollok & Bailey. Major Bailey made a copy of what I had written, and filed it as an amendment, February 29, 1876.

Int. 109. How long did you remain in Washington after your arrival there, on Saturday, February 26, 1876?

Ans. I am not quite sure, but I remember that I was there on the 3d of March, 1876, the day my patent of March 7, 1876, was allowed. I remembered this from the fact that it was my birthday, and the allowance of the patent came as a sort of birthday present. This made such an impression upon my mind that I am perfectly certain of being in Washington at that time. I know I was in Boston on the 7th of March, so left Washington somewhere between the 3d and 7th.

Int. 110. Had you, prior to the issue of your patent of March 7, 1876, constructed any other electric-speaking telephones than the two membrane instruments described in your answer to Interrogatory 82, which were made, respectively, in June and July, 1875?

Ans. No; excepting so far as the construction of these instruments was modified in different experiments.

Int. 111. When did you first try a variable-resistance electric-speaking telephone transmitter constructed upon the plan which

grew out of your contemplation of the mode of operation of your spark-arrester, as you have explained, and what sort of a receiver was first used with it, and how did the trials of such an apparatus result?

Ans. I first tried such variable-resistance transmitters some time in March, 1876. The receiver employed was a tuned-reed receiver like those shown in Fig. 5 of my patent of March 7, 1876. The reed of the receiver was damped by being pressed firmly against the ear. With this arrangement intelligible speech was produced, and I myself was able to hear from the steel-spring armature pressed against my ear many words that I could understand, which had been uttered by Mr. Watson to the membrane of the variable-resistance transmitter employed. If I remember rightly, familiar quotations — like “To be, or not to be,” etc., — counting — like 1, 2, 3, 4, 5, etc., — were very readily understood. But expectancy had a good deal to do with this, as language read from a book was not, I think, as a rule, understood, although a few words could be made out here and there.

Int. 112. If you recall to mind the date on which for the first time articulate speech was transmitted and reproduced by the apparatus referred to in the last interrogatory and answer, so as to be audibly recognized by a listener, will you give it?

Ans. If I remember rightly, a crude apparatus of the kind was tried on the 9th of March, 1876, and audible sounds were produced from the receiver. My recollection is that a sort of muttering effect was heard from the steel-spring receiver pressed against the ear, when a person spoke to the variable-resistance transmitter. Encouraged by this, a more carefully constructed apparatus was made, which was tried next day, — I think March 10, 1876, — and with this apparatus there was no mistake at all about the fact of articulate speech being transmitted by the instrument. On that occasion complete words and sentences were understood.

Int. 113. To what sort of electrical work was the principal part of the time devoted by you, which you were able to spare from your professional duties in March and April, 1876?

Ans. The chief part of the time — at the earnest solicitation of my associates, Mr. Sanders and Mr. Hubbard — was devoted to

experiments relating to the development of the autograph telegraph for which I had obtained a patent on April 6, 1875. They had, at that time, the idea that that development of multiple telegraphy would prove of more immediate pecuniary value than the other features of my inventions. A considerable portion of my time, however, was devoted to experiments relating to the speaking telephone. But this was done rather in opposition to the wishes of my associates, and in consequence of the very great interest that I myself, personally, took in that department of my investigations.

Int. 114. What was the particular liquid used in your variable-resistance transmitter on March 10, 1876, when you first successfully transmitted and reproduced articulate speech?

Ans. Acidulated water. Water containing a little sulphuric acid.

Int. 115. Why did you thus acidulate the water so used?

Ans. To increase the conductivity of the water, and render it more suitable for a laboratory experiment where only a short circuit was employed.

Int. 116. In the specification of your patent No. 186,787, of January 30, 1877, you used the following language:

"It is, therefore, by no means necessary or essential that the transmitting instrument should be of the same construction as the receiving instrument. Any instrument receiving and transmitting the impression of agitated air may be used as the transmitter, although, for convenience and for reciprocal communication I prefer to use like instruments at either end of an electrical wire. I have heretofore described and exhibited such other means of transmitting sound, as will be seen by reference to the proceedings of the American Academy of Arts and Sciences, Volume XII."

To what particular publication did you thus allude; and if you have a copy, will you produce it?

Ans. I alluded to a paper by myself, entitled "Researches in Telephony," presented May 10, 1876, by the corresponding secretary, and published in the Proceedings of the American Academy of Arts and Sciences, Volume XII. I produce a copy of the paper referred to.

[*Counsel for defendants puts in evidence the paper just produced by the witness, and it is marked "Defendants' Exhibit Bell's Ameri-*

can Academy Paper of May 10, 1876, H. L. H., Special Examiner."]

Int. 117. Did you yourself read this paper before the American Academy of Arts and Sciences on May 10, 1876?

Ans. I did.

Int. 118. Did you, at the time, exhibit any electrical apparatus, and if so, what?

Ans. Yes, I did exhibit quite a number of pieces of apparatus. I do not know that I can recall them all, but I remember some. I exhibited the membrane telephones referred to in section 12 of the paper. I also exhibited what was called, in the former telephone cases, the "iron-box" receiver. I also showed, I think, some circuit-breaking transmitters and tuned-reed receivers, and, I think, also showed a liquid speaking telephone transmitter, like that referred to in section 13 of the paper, but I am not quite certain of this. If it was shown, as I think it was, it was not shown in operation. I had a wire connecting the hall of the American Academy with my private room in the Boston University, which was in the same street and almost next door. In my room at the Boston University, I had a parlor organ, the reeds of which were arranged to interrupt, in vibrating, a voltaic circuit. This was connected with the iron-box receiver in the hall of the Academy, and music was transmitted from the one place to the other. At the close of the meeting, the membrane telephones referred to in section 12 were shown in operation. I do not remember exactly where the two ends of the circuit were. One instrument was in the hall of the Academy, and I think that the other was in the Athenæum Library, in the same building. At all events, the instruments were shown in operation, and some of the members of the Academy tested them on that occasion.

Int. 119. When did you construct such membrane telephone instruments as are described in section 12 of your American Academy paper of May 10, 1876?

Ans. I think in March, 1876, about the middle or latter part of the month.

Int. 120. When did you next publicly exhibit your electric speaking telephones, and address a public assembly upon the subject?

Ans. On the 25th of May, 1876, I read substantially the same paper given to the American Academy, before the 197th Meeting of the Society of Arts, held in the Massachusetts Institute of Technology, in Boston, Mass.

A report of this meeting, written by the secretary, appeared in the *Boston Evening Transcript* of May 31, 1876, a copy of which is now before me. The account of my address commences as follows :

“RESEARCHES IN TELEPHONY.

Professor A. Graham Bell read a paper, illustrated by successful experiments, on ‘Telephony,’ or the telegraphing of musical sounds, from which the following are extracts” . . .

Then follow quotations which are substantially similar to those made to the American Academy of Arts and Sciences on the 10th of May. The article concludes as follows :

“The experiments were novel and successful and witnessed by a large audience, by whom a vote of thanks was passed to Professor Bell for his interesting paper.”

Int. 121. Did you exhibit electrical apparatus embodying your inventions, at the Centennial Exhibition in Philadelphia, and if so, when first? In this connection you may state briefly the circumstances under which you came to make such exhibition.

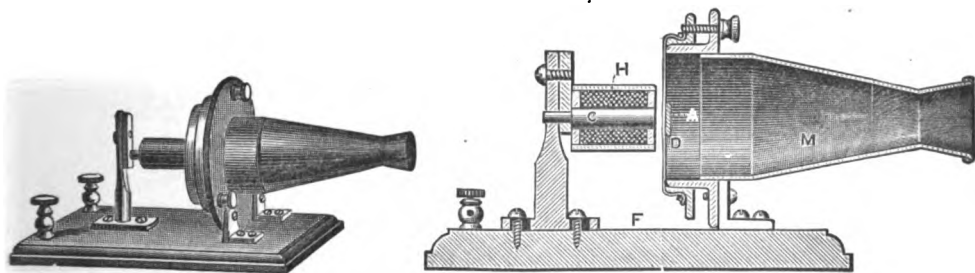
Ans. Yes ; I placed such apparatus on exhibition at the Centennial, in June, 1876, and the instruments remained on exhibition there until the close of the Centennial. The exhibit consisted of two membrane speaking telephones having iron or steel patches glued to the membranes ; a liquid speaking telephone transmitter ; an iron-box receiver with iron or steel diaphragm ; then there was also a telephonic organ with reeds arranged to make and break contact, for the production of musical effects ; and two current-interrupters with corresponding tuned-reed receivers having vibratory circuit-breakers attached, which operated Morse sounders in a local circuit, to illustrate my method of multiple telegraphy, and the method of causing the vibratory motion of the tuned reed to open or close a local circuit containing an ordinary telegraphic apparatus. I also exhibited a U-shaped permanent magnet, which could be set in vibration, like a tuning-fork, for the purpose of illustrating the production of magneto-electric currents corresponding to sonorous vibrations. In

addition to these instruments, I exhibited an apparatus for studying optically the forms of electrical undulations. It was, in effect, the manometric capsule of Koenig. A thin sheet of iron or steel was attached to the membrane of the capsule, and acted upon by the pole of an electro-magnet.

I may have exhibited other apparatus, but these are all that I remember at the present time. I went down to Philadelphia for the purpose of exhibiting my apparatus to the judges. The exhibition was to take place on Sunday, the 25th of June, 1876, and I was there the day before, arranging wires, batteries, etc., and getting my instruments in order for the proposed exhibit. I think I arrived in Philadelphia on Friday night, the 23d of June, and if not then, on Saturday morning, June 24. I exhibited some of my apparatus in operation before the judges on Sunday, the 25th of June, and I think I returned to Boston the same night.

Int. 122. Please describe the electric speaking telephone instruments which you exhibited at the Centennial Exhibition, on Sunday, June 25, 1876, giving the dimensions of the principal parts. For this purpose, I will furnish you with drawings which were contained in the records of former telephone suits, and were reproduced in the official report of *The Telephone Cases* on appeal before the Supreme Court of the United States. (126 U. S. 322, 323.)

Ans. I will begin with the *Centennial Single-Pole Magneto Telephone*. The first drawing shows it in perspective, and the second in section.



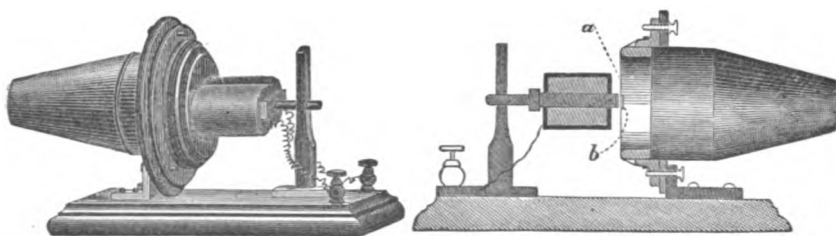
The dimensions were as follows :

Length of cone	$5\frac{3}{4}$ inches
Diameter of membrane	3 "
Length of spool	$1\frac{3}{8}$ "
Diameter of spool	$1\frac{3}{8}$ "

Referring to the sectional drawing: The armature, A, was composed of a small piece of thin sheet iron or steel, which was glued to the centre of the membrane diaphragm, D. The diaphragm D, came between the armature, A, and the pole of the electro-magnet, which was composed of a single straight iron core, C, surrounded by a helix, H, of insulated copper wire. M is a mouth-piece of japanned tin. This was also used as an ear-piece or hearing tube when the telephone was employed as a receiver. F is a frame supporting the whole apparatus. The distance of the pole of the electro-magnet from the membrane carrying the armature could be adjusted as required by means of slots and set-screws in the base of the standard supporting it. The membrane was attached to a brass straining ring, and the tension of the membrane could be adjusted by the operation of screws, as shown.

I will now describe the *Centennial Double-Pole Magneto Telephone*.

Here, the drawings, as before, are a perspective view and a sectional view.



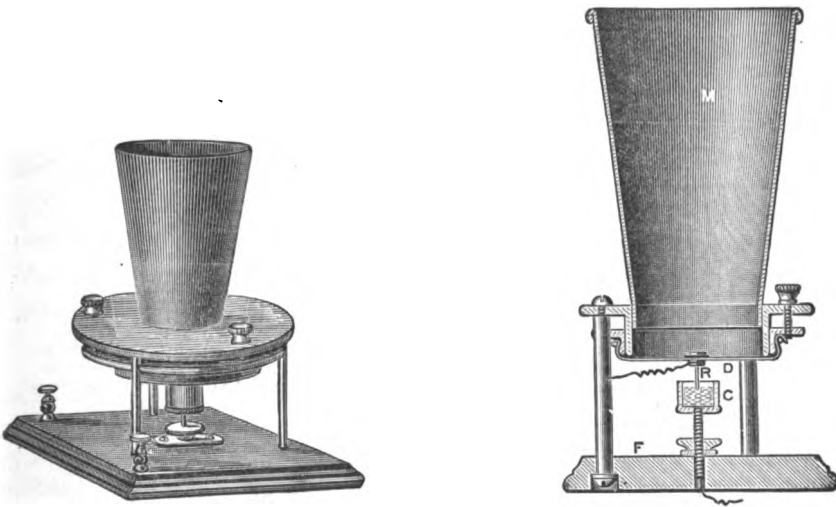
The dimensions were as follows :

Length of cone	4 $\frac{3}{4}$ inches
Diameter of membrane	3 "
Length of spools	1 $\frac{3}{4}$ "
Diameter of spools.	1 $\frac{3}{8}$ "

The construction of the instrument was similar to that of the other. There was a double-pole electro-magnet instead of a single pole, and the armature of sheet iron or steel, instead of being a small central patch, was an elongated strip, so as to face both poles of the electro-magnet. These are the chief differences. The membrane diaphragm is lettered *a*, and the armature is lettered *b*. The mouth-piece was

originally just the same as in the single-pole magneto telephone, but before this drawing was made, the outer part had been broken off.

I will now describe the *Centennial Liquid Transmitter*, by the aid of two drawings, one of which is a perspective view and the other a sectional view.

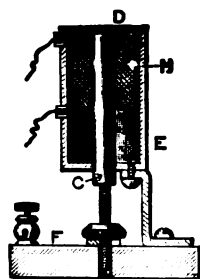
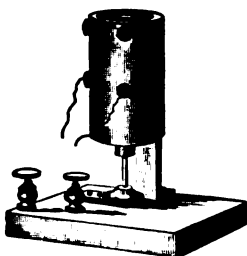


The dimensions were as follows :

Diameter of membrane	3 inches
Diameter of cup	$\frac{3}{4}$ "
Depth of cup	$\frac{1}{2}$ "
Length of cone	6 "

D is the diaphragm ; R is the rod attached to the centre of the diaphragm, and dipping into the liquid in the cup C. F, supporting-frame, and M the mouth-piece. This also has a straining-ring with adjusting-screws like that used in the single and double-pole membrane telephones already described. Indeed, they were all three made from the same casting. The cup is supported upon a screw, by which it can be adjusted vertically to vary the depth of immersion of the lower end of the rod R.

I will now describe the *Centennial Iron-Box Receiver*, by the aid of two drawings, one of which is in perspective, and the other in section.



The dimensions were as follows :

Diameter of tube	.	.	.	.	1 $\frac{1}{4}$ inches.
Length of tube	.	.	.	.	3 "

The drawings show four holes in the side of the iron box. These were not in the instrument as exhibited at the Centennial, but were made subsequently in the course of experiments in which two helices, one on top of the other, were employed. When the instrument was used at the Centennial, only one helix H was employed, but I think this filled the entire box, instead of only a portion of it, as shown in these drawings. I also think the terminals of the coil came out below. A diaphragm D of sheet iron or steel formed the lid of the iron-box receiver, E. This is shown in the sectional drawing, but has been omitted from the perspective view. The core C of this cylindrical electro-magnet could be adjusted by means of the screw and nut shown at one end, so that the other end should come very close to the diaphragm D without touching it. F is the supporting-frame.

Int. 123. What electrical instrument did you actually show in operation at the Centennial Exhibition, on Sunday, June 25, 1876?

Ans. The multiple-telegraph apparatus, with current-interrupters and tuned-reed receivers; also the Centennial Single-Pole Magneto Telephone; the Centennial Double-Pole Magneto Telephone; and the Centennial Iron-Box Receiver.

Int. 124. Who were present at this exhibition of Sunday, June 25, 1876?

Ans. A great many people were present, but I can only recall the names of a few: Dom Pedro, the Emperor of Brazil; Sir William Thomson, Professor James C. Watson, of Ann Arbor,

Mich., Professor T. Sterry Hunt, Professor George F. Barker, Mr. Elisha Gray, Mr. William H. Hubbard, nephew of Hon. Gardiner G. Hubbard. Mr. William Hubbard assisted me in the experiments. I recall also, Professor Hilgard, Dr. Draper and Dr. Koenig — the inventor of the manometric capsule — as among those present.

Int. 125. I show you a letter dated June 25, 1876, addressed to you. Who wrote it, and when did you receive it?

Ans. It was written by Professor T. Sterry Hunt, and was received by me on or about the date it bears. I either received it on the 25th of June, 1876, before I left Philadelphia, or it reached me by mail, in due course, after that date.

Int. 126. Please read this letter as a part of your present answer.

Ans. The letter is as follows :

CONTINENTAL HOTEL, PHILA., June 25, 1876.

DEAR MR. BELL :

I am informed that you leave tonight for Boston, so I take this way of congratulating you on your success today. I returned to my hotel with Sir Win. Thomson, and dined with him. He speaks with much enthusiasm of your achievement. What yesterday he would have declared impossible he has today seen realized, and he declares it the most wonderful thing he has seen in America. You speak of it as an embryo invention, but to him it seems already complete, and he declares that, before long, friends will whisper their secrets over the electric wire.

Your undulating current he declares a great and happy conception.

All this he discussed partly with Dr. Bache and more at length with Sir Redmond Barry and Sir John Hawkshaw. Sir William leaves here on Friday for Montreal, and will visit Boston for a day or two before sailing, which will be from New York, July 19.

Thinking you would be glad to hear the judgment of one so eminent, I have written you this, and I am, my dear Mr. Bell,

Always truly yours,

T. STERRY HUNT.

P. S. — Do you know anything of Brücher's system of visible speech, of which one of the Austrian judges spoke today? It seems very like your father's.

GRAHAM BELL, Esq.

Int. 127. Previously to sending to the Centennial Exhibition at Philadelphia the four electric speaking telephone instruments which you have described in your answer to Interrogatory 122, had you

tested all of them in Boston, and if so, with what results, and how had they been coupled up?

Ans. Yes; I had tested them all, and had successfully transmitted intelligible speech by means of them. The liquid transmitter was coupled up in metallic circuit with the iron-box receiver and a battery. The single-pole and double-pole magneto telephones were coupled up with one another in metallic circuit with a battery, and tested for reciprocal communication. In actual use each instrument had been used alternately as a transmitter and a receiver. I had also, previously to the exhibition, tested the iron-box receiver as a receiver for the magneto telephones with membrane diaphragms, and found it to work well with either the single-pole or double-pole magneto telephone used as a transmitter.

Int. 128. When testing the Centennial Single-Pole Magneto Telephone, and the Centennial Double-Pole Magneto Telephone, did you make use of the japanned tin cones which were made for them?

Ans. I tried them and satisfied myself that they would work; but in my own experiments and tests I preferred to omit them, and simply speak with my mouth as near the membrane of the transmitter as possible. The cones or mouth-pieces were more for show than anything else, — to give a finish to the apparatus.

Int. 129. When was the iron-box magneto telephone instrument with metallic diaphragm constructed; what was its origin, and how had it been used, up to the time when it was sent to the Centennial Exhibition?

Ans. I am not sure at the present moment of the date of construction. I am inclined to think it was about the end of March or beginning of April, 1876; but its origin is very clear in my mind. It had long been my custom to use a tuned-reed receiver as a receiver for sounds different from that normally produced by the free vibration of the reed. I got rid of the free vibration as much as possible by damping the reed by pressing my ear closely against it, and I was then able to perceive forced vibrations. I had used such a receiver in my experiments with a liquid transmitter about the 10th of March, 1876, and had heard articulate speech — both words and sentences — emitted by a tuned-reed receiver when the reed was

damped against my ear. The only difficulty in using an arrangement of this kind as a receiver for articulate speech was its tendency to vibrate at a definite rate. Its free vibration was a disadvantage for this purpose. It occurred to me, therefore, to fetter the free end of the reed, so as to reduce its tendency to vibrate at a definite rate as much as possible. For this purpose I proposed to clamp both ends, and attach them to two of the poles of a three-legged electro-magnet. The electro-magnet was to consist of an iron or steel back-piece for the support of three parallel legs, the central leg or core being surrounded by a helix of insulated copper wire, and capable of adjustment. The outer legs were to be uncovered; the iron or steel reed was to form a bridge between these two uncovered legs, and to be clamped to them both. The central leg or core of the electro-magnet was to be adjusted so as to come very near to the central portion of the doubly-clamped reed without touching it. When a current traversed the coil surrounding the central leg, the whole arrangement would become magnetic; the end of the central leg constituting one pole of the magnet so formed, and the ends of the outer legs the other pole. I presumed that the reed, being clamped to the ends of the outer legs, would acquire the same polarity and become a constituent part of the magnet; so that, in effect, the end of the central core formed one pole of the magnet, and the centre of the reed the opposite pole. I saw that the outer legs might be multiplied in number without affecting the operation of the instrument. There might, indeed, be an outer circle of legs, and theoretically the top of each one should be of opposite polarity to the end of the central core. From these considerations it became obvious that a cylindrical iron box with a central iron core, as shown in my Centennial Iron-Box Receiver, would answer the same purpose. The end of the central core would constitute one pole of the tubular magnet thus formed, and the iron rim of the box the other pole. By placing upon it a lid or diaphragm of iron or steel, we had an armature that was damped all around, and polarized by contact with the rim of the box. The end of the central core would then constitute one pole of the magnet, and the centre of the diaphragm or lid the opposite pole. This seemed to me an especially advantageous arrangement. This was the origin of the iron-box

receiver, and in order to damp the vibrations of the lid or diaphragm still further, the ear was placed closely against the lid as it had been in former experiments against the reed of the tuned-reed receiver. This was the way in which the instrument was generally employed, and it was so used at the Centennial Exhibition. The listeners were instructed to press their ears firmly against the lid of the iron-box receiver.

Int. 130. Did you make other tubular iron-box magneto-telephone instruments with metallic diaphragms, and if, so when, and how did they compare in dimensions with the Centennial Iron-Box Receiver which you have described?

Ans. Yes; I ordered the construction of two others, in June, 1876. The diameter of the iron box was considerably greater, and the iron diaphragm somewhat thinner than in the case of the Centennial Iron-Box Receiver.

Int. 131. Was the Centennial Iron-Box Receiver tried as a transmitting telephone instrument; and if so, when, and with what results?

Ans. Yes; it had been tried in the spring and early summer of 1876 as a transmitter, before being sent to the Centennial. It had been placed in circuit with one of the membrane diaphragm telephone instruments as a convenient receiver; and on a number of occasions the experiment had been made to see whether we could obtain reciprocal communication by talking to the iron-box instrument as a transmitter, and using the membrane telephone as a receiver. Under such circumstances, speech sounds were transmitted, but not nearly so well as when the membrane telephone was used as a transmitter and the iron box as a receiver.

Int. 132. What was the reason why that particular Centennial Iron-Box Receiver, when put in circuit with one of the membrane-diaphragm instruments which you had constructed, was not so good a magneto telephone transmitter as such membrane-diaphragm instrument, when the two were used reciprocally; and what led you to make the subsequently constructed iron-box magneto instruments with metallic diaphragms of larger dimensions, as mentioned by you.

Ans. There were two reasons why speech was not so well heard when the iron box was used as a transmitter and the membrane

telephone as a receiver, as when the converse arrangement was made. In the first place, I could not get my ear into actual contact with the armature of the membrane telephone; and it was not therefore as sensitive a receiving instrument as the iron-box instrument. In the second place, the iron or steel diaphragm of the iron-box instrument was of such small diameter and of such stiff material that it was not so well adapted to be vibrated by the voice as the membrane instrument. The subsequently constructed iron-box instruments were prepared for use in an experiment that was proposed to be made between Boston and Philadelphia. If the judges of the Centennial had requested the experiment, I was prepared to attempt to transmit articulate speech from Boston to Philadelphia. For this purpose, I thought it advisable that the coils or helices used in my telephones — both transmitters and receivers — should have a very great number of turns to enable them to transmit or receive sounds on a circuit of such resistance as the line between Boston and Philadelphia. For this purpose, it seemed advisable that the iron box should have an increased interior capacity, and be able to receive a coil of greater diameter. I think, also, that I had the impression that a thinner diaphragm, and one of greater diameter than that used in the Centennial Iron-Box Instrument, would render it more sensitive to vibration.

Int. 133. When did you first make any other magneto telephone having an iron diaphragm. and how was it arranged and used?

Ans. About the end of June, 1876, I made an iron diaphragm larger in diameter than could well be placed on the iron-box instrument, and used it both for receiving and transmitting speech in a magneto telephone. This diaphragm is still in existence, and was put in evidence in the *Dowd* suit. I insert here a picture of it, very much reduced in size.



The actual diameter of the diaphragm is 5 inches. This consisted of a circular sheet of Tagger's iron, attached at its edge to a metallic rim which carried three metallic rods, as shown. The other ends of these rods are tapped with screw-holes, so that the arrangement can be fastened in position to a frame. In using this metallic diaphragm, experiments were made with electro-magnets of different kinds — I think both single and double-pole. The electro-magnet tried was fastened in position within the three rods, with its pole or poles almost touching the diaphragm. The diaphragm would then be tested as a transmitter by speaking with the mouth in close contact with it, an iron-box instrument or membrane telephone being used as a receiver. And it was tested as a receiver by placing the ear against the iron diaphragm, while some person spoke to the iron-box instrument or membrane telephone at the other end of the circuit. I think this Tagger's iron diaphragm was in existence on the 30th of June, 1876, but whether it was made at that time or at some earlier date, I cannot now be sure.

Int. 134. When was this Tagger's iron diaphragm actually used as part of a magneto electric-speaking telephone, in the manner you have described in your last preceding answer, and with what results?

Ans. It was so used on the 30th of June, 1876, in connection with a membrane magneto telephone. The two instruments employed had such high-resistance coils as to give the circuit a resistance equivalent to more than 300 miles of telegraph wire. Under these circumstances, and with a very small battery upon the circuit, sounds were heard from the sheet of Tagger's iron, when a person spoke to the membrane magneto telephone; and sounds were heard from the magneto telephone when a person spoke against the sheet of Tagger's iron. This sheet of Tagger's iron was used in quite a number of experiments, both for receiving and transmitting speech, during the month of July, 1876; sometimes with and sometimes without a battery upon the circuit.

Int. 135. I show you a letter, dated July 2, 1867, and addressed to Mr. William Hubbard. Did you write it, and if so, when, and to whom did you send it?

Ans. I wrote it on July 2, 1876, but by a slip of the pen I transposed the 6 and 7, thus making it appear to be written in 1867.

I sent it to Mr. William H. Hubbard who was then in Philadelphia, in charge of my exhibit.

Int. 136. Will you please read the letter as part of your present answer, omitting the merely personal and family matters?

Ans. I read from it as follows :

CAMBRIDGE, MASS., July 2d, 1867.

MY DEAR WILLIE, —

For the fourth time today I commence an epistle to you. I am determined to write you a letter in spite of all the obstructions thrown in my way—for I think you deserve a real good-hearted letter as long as from here to Philadelphia for all that you have done for me and my telegraph. . . .

Willie Winlock and Bert Eustace went into Boston to help me on Thursday in case it was decided to work my instruments between Boston and Philadelphia. They were to sing for me. . . .

Having completed my list of messages, I must really now speak of my telegraphic instruments. I can't tell you how glad I was to receive your telegram about your exhibit before Sir William. Mrs. Hubbard and *all the family* feel very proud of you for being able to exhibit so successfully my electrical apparatus. I had no idea that you would have to remove the apparatus to the judges' hall. Poor fellow, what a time you must have had! I really do feel very proud of you that you should have made everything go smoothly. I am very anxious about Saturday. What should I have done without you or rather what should I do now without you? I am afraid you must think me very ungrateful for not having written, but the fact is, that in preparing for transmitting sounds to Philadelphia from here, I made such a startling discovery that I have been unable to do anything else since but experiment. In order to attempt the transmission of speech to Philadelphia, it was necessary to have a telephone constructed, the magnet of which should have a resistance equivalent to a considerable portion of the total resistance of the telegraph line between here and Philadelphia. The resistance of the line is over 5000 ohms. Now I have had two magnets made, the coils of which offer a resistance of 3250 ohms both together. It would require a battery of many cells in order to operate a Morse sounder through such a resistance. It is as great a resistance as 325 miles of well-insulated telegraph wire. My discovery was that I could work my apparatus with *one cell of battery* through this resistance. I am sure by substituting a *permanent magnet* for the pole of the electro-magnet, I could work it *without a battery at all*.

With love and best wishes,

Yours sincerely,

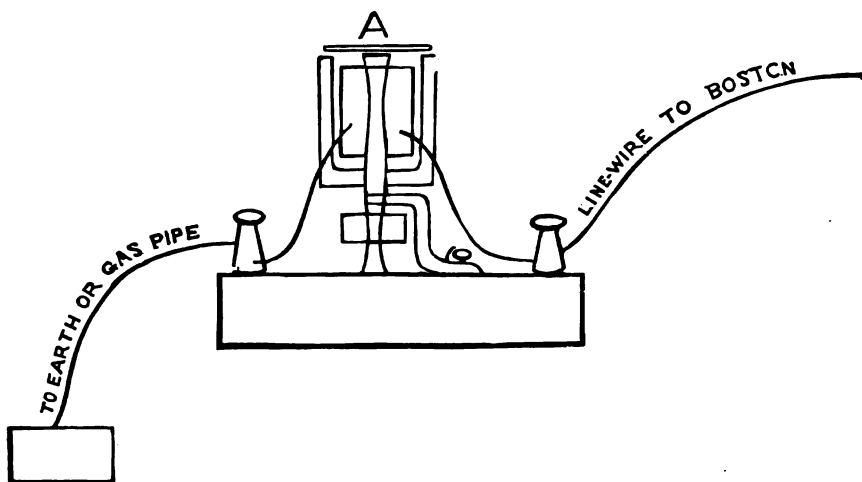
A. GRAHAM BELL.

Mr. WILLIAM HUBBARD,

East. Gall., M. B.,

Exhibition Building, Philadelphia.

P. S. Should I send on apparatus to Philadelphia and you make the connections, simply connect the instr. with the line wire and the earth like this, —



A. G. B.

You can increase musical sounds by resting bridge of violin against A.

Int. 137. In this letter from which you have just read, you said :

“I am sure by substituting a *permanent magnet* for the pole of the electro-magnet, I could work it *without a battery at all.*” . . .

Was the use of a permanently-magnetized electro-magnet in an electric speaking telephone a novel idea to you at that date — July 2, 1876?

Ans. By no manner of means. Such an idea was in my mind when the speaking telephone was first conceived by me in the summer of 1874, and had always been present in my mind from that time onward.

Int. 138. Was the use of a permanent steel magnet, either as the core of an electro-magnet, or as the means for magnetizing the core of an electro-magnet by being put in magnetical contact therewith for the purposes of an electric speaking telephone with no battery in circuit, a novel idea to you at the date of this letter, — July 2, 1876?

Ans. No, indeed. It was at that time a very old idea with me.

Int. 139. Why did you use a battery in circuit with your elec-

tric speaking telephones, in preference to permanently magnetizing the core of the electro-magnet of each instrument?

Ans. Because I could in these experiments produce a more powerful magnetic condition in the core by means of a battery than by means of a permanent magnet. I had made numerous experiments with magneto speaking telephones without any battery upon the circuit, and I understood at the time that the magneto-electric impulses were due to residual magnetism, that the cores indeed acted as very weak permanent magnets, and in this case I presumed that the audible effects produced were weaker than if the cores had been permanently magnetized, or had been magnetized by the influence of a permanent magnet. On the other hand, I understood that the magnetic condition of the core of an electro-magnet, when a powerful battery current was passed through the coil surrounding it, was much greater than could be produced by permanent magnetism alone in the core, or by magnetism produced in the core by the influence of a permanent magnet in contact with it or in its vicinity. I therefore presumed that in the case of my magneto-electric telephones the audible effects produced when a battery was used were more powerful than would have been the case if the cores had been permanently magnetized, or had been magnetized by the influence of a permanent magnet. I always knew that the function of the battery was to magnetize the core, and understood that in electrical speaking telephones, like those I had devised, electro-magnets and permanent magnets were the equivalents of one another for the purposes of my invention, but that upon short circuits, such as those employed in my laboratory experiments, the electro-magnet was more powerful, and, therefore, better adapted for the purpose. When I speak of electro-magnets and permanent magnets being the equivalents of one another, I mean that for the purposes of my invention electro-magnets with permanently-magnetized cores and without any battery current passing through the coil were the equivalents of electro-magnets with soft-iron cores rendered magnetical by the passage of a battery current through the coil, and I understood that the magnetical condition in the latter case was stronger than in the former, and that therefore, in laboratory experiments and upon short circuits, the latter would produce louder effects than the former, if combined

in a speaking telephone. I always knew this, from the first time the speaking telephone was conceived, in the summer of 1874, and, for the reasons stated, I preferred to employ battery currents for the purpose of magnetizing the cores.

Int. 140. For what purpose did Mr. William H. Hubbard remain in Philadelphia after your departure on the night of June 25, 1876?

Ans. After the exhibition on the 25th of June, 1876, the judges of the Centennial Exhibition had expressed the desire to examine the speaking telephones shown, again, so as to give them a further test. As I could not remain in Philadelphia on account of engagements in Boston, Mr. William Hubbard undertook to show the apparatus to the judges.

Int. 141. Was Mr. William H. Hubbard expected to exhibit, or did he, to your knowledge, exhibit anything but your electric speaking telephones?

Ans. To my knowledge he exhibited only the speaking telephones.

Int. 142. In your letter to him of July 2, 1876, you said :

"I think you deserve a real good-hearted letter as long as from here to Philadelphia for all that you have done for me and my telegraph . . .

Having completed my list of messages, I must really now speak of my telegraphic instruments. I can't tell you how glad I was to receive your telegram about your exhibit before Sir William. . . .

In order to attempt the transmission of speech to Philadelphia it was necessary to have a telephone constructed, the magnet of which should have a resistance equivalent to a considerable portion of the total resistance of the telegraph line between here and Philadelphia."

To what did you refer, in the parts of the letter thus quoted, as "my telegraph," and "my telegraphic instruments," and "a telephone"?

Ans. Where I spoke of "my telegraph," and "my telegraphic instruments," I alluded to the speaking telephones that had been shown to the judges. At the date when this letter was written — July 2, 1876,— the word "telephone" had not yet entirely usurped the place of the word "telegraph" in describing an instrument for the transmission of articulate speech by electricity. My speaking tele-

phone was, at that time, spoken of, by me and by others, sometimes as a "telegraphic instrument," sometimes as a "telephonic apparatus," and sometimes as a "telephone," and at that time I still alluded to it as a form of telegraph.

Mr. William Hubbard had come down to Philadelphia to assist me in exhibiting my apparatus before the judges, and when they desired to have a further test of the speaking telephones shown, I thought Mr. William Hubbard might be able to superintend the test, although he was no electrician, and knew nothing of my apparatus further than any well-educated young man would by visiting my laboratory occasionally. I thought he might superintend the re-testing of the apparatus, because the wires had already been run, and Mr. Hubbard had helped me to arrange the apparatus on the circuit; so that all he had to do was to put the instruments in the places where they had been before, connect the screw-cups and turn on the battery. The judges, however, desired to have the speaking telephones removed entirely from the place where they were tested on the 25th of June, and have them set up in the judges' hall. I had hardly supposed that Mr. William Hubbard would have been competent to do this, because he was no electrician and knew very little about the apparatus. When, however, I learned that he had not only done this, but had succeeded in getting the apparatus to work [to the satisfaction of the judges, I thought that perhaps he might be trusted to superintend matters at the Philadelphia end of the line, in the experiment I proposed to make, of transmitting speech from Boston to Philadelphia. I wrote him the letter of July 2, 1876, to show him how much pleased and delighted I had been with what he had done for me, and to give him instructions how to connect the new telephones I proposed to send to Philadelphia for trial on the line between Philadelphia and Boston. The drawing in the letter shows one of the new iron-box receivers with metallic diaphragm (A), and high-resistance coil of many turns of fine wire, which had been constructed for use in this experiment. By the drawing I tried to show him that all he had to do was to connect one of the terminals with the "line wire to Boston," and the other "to earth or gas pipe." The word "telephone," used in the letter, refers to the iron-box receiver shown in the drawing, and to other

telephones with high-resistance coils which I was then testing in Boston.

Int. 143. What special object had you in view during your experiments with electric-speaking telephones after June 25, 1876; and what was the character of the instruments which you constructed and tried between that date and your visit to your father's home, in Canada, later in the same summer?

Ans. The special object I had was to ascertain the best construction of my telephones for operation on long lines. Before this, my work had consisted largely of laboratory experiments with telephones on short circuits. At that time — June 25, 1876, — I felt that the telephones transmitted speech with sufficient distinctness to be put into practical use, and that, therefore, my chief efforts should be directed to adapting them for use on long lines of great resistance. The coils which had been previously employed in the construction of my telephones had usually been of low resistance — say, from 2 to 25 ohms, or thereabouts. While such coils were perfectly efficient for mere laboratory experiments, it was hardly to be expected that they would work well on a long line like that from Boston to Philadelphia, for the resistance of the line alone must have been many hundreds of ohms. In order to obtain the best effects upon a line of such resistance as that, I believed it to be necessary, or at least advisable, that the electro-magnets employed in my telephones should have coils composed of very many turns of fine wire, so that the resistance of the coils employed should be very much greater than any I had used before. The instruments, therefore, which were constructed during the period alluded to were largely characterized by coils of great resistance, wound with fine wire. In testing these instruments I tried to imitate the conditions of a real line of great length, by introducing into the circuit artificial resistances of great amount to represent the line. I sought to arrive at that arrangement of coil, etc., that would give the best audible results through a very great resistance. Instead of employing coils measuring from 2 to 25 ohms resistance, as I had formerly done, I constructed, during the period of time inquired about, telephones with coils measuring several hundred ohms. Some of the coils measured 1650 ohms, and others 1800 ohms. Instead of using the telephones

on short circuits, I introduced into my circuits resistances of many thousands of ohms. In some experiments the artificial resistance introduced measured 37,310 ohms, bringing the total resistance of the circuit—including the coils of the telephones used—up to 40,760 ohms, a resistance equivalent to many hundred miles of telegraph wire. Nearly all the experiments made during the period specified had relation to the conditions required on real lines of great length.

Int. 144. Did you, during the period mentioned in the last preceding interrogatory, make use of a real telegraph line in testing your electric speaking telephone instruments, and, if so, how many times, what lines, and under what circumstances?

Ans. Yes. I made three experiments upon lines belonging to the Atlantic & Pacific Telegraph Company during the first two weeks of July, 1876. I can recall the dates of these experiments by reference to a paragraph that appeared in the *Boston Evening Transcript* July 13, 1876, page 1, column 3, which I have seen today at the office of that newspaper. The paragraph is as follows:

“During some electrical experiments last evening in the transmission of vocal sounds and instrumental music by means of the ordinary telegraph wire, an organ in the Atlantic and Pacific Telegraph Company's office, in the Equitable Building, on Milk Street, was played, and the different tunes were easily distinguished by the operator in New York, and conversation was carried on between the Equitable Building and the office on State Street.”

The newspaper reporter has got the results of the three experiments mixed up somewhat. Experiments were made on the 12th of July, in the Equitable Building, in the presence of Sir William Thomson, and with his assistance; but this was the third of the series of experiments that had been made upon this line. The telephonic organ which had been connected with the line to New York, when different tunes were distinguished by the operator in New York, had been tried at the preceding experiments the Sunday before, and the first experiment was made on the Friday before that. Thus, the first experiment was made on Friday, July 7, 1876; the second on Sunday, July 9, 1876, and the third on Wednesday, July 12, 1876. The reporter stated that conversation was carried on “between the Equitable Building and the office on State Street.”

In all the experiments, however, in which conversation was transmitted, both telephones were in the Equitable Building, but in different rooms. The battery employed was in State Street, and the other end of the line was grounded at Rye Beach—I should think about sixty miles from Boston. In the second experiment, a parlor organ was employed, the reeds of which in vibrating made and broke the circuit to New York. In this case the battery was in State Street, the telephonic organ in the Equitable Building, and the other end of the line was grounded in New York through one of the ordinary telegraph relays there. I telegraphed to New York by another line, and asked the operator there to place his ear to his relay, and let us know if he could hear anything. While this was going on, I played a variety of tunes upon the organ. Presently a telegram was received from the operator in New York to the effect that he could hear “elegantly.” We then telegraphed back to New York to ask whether he could recognize any of the tunes, and he replied, laconically, “Yankee Doodle.” On this occasion—Sunday, July 9—I tried my transmitting and receiving telephones on the circuit to New York, in place of the telephonic organ. The battery was in State Street, the two telephones were in neighboring rooms in the Equitable Building, and the line was grounded in New York, through an ordinary relay there. I do not remember exactly what the result of this experiment was. I think that faint sounds were heard from one of the telephones when a person spoke at the other, but the two instruments were not quite out of earshot of one another, so that the experiment was inconclusive. I think, also, but am not quite sure, that we telegraphed the operator in New York to put his ear to his relay and see if he could hear anything. I think his reply was that he could not hear anything. Both on the first experiment and on the second experiment words and sentences were intelligibly transmitted when the telephones were in circuit with the Rye Beach line. On the third experiment, made July 12, 1876, the same instruments were used in the presence of Sir William Thomson. On this occasion I remember we telegraphed to New York, and had two wires crossed there, and we introduced this loop, exceeding 400 miles of wire, into our telephonic circuit. I remember that there had been a storm a short time before—probably the day before—

and on that account many of the telegraph wires were out of order, and on this occasion, when the New York wires were crossed, there seemed to have been some trouble on the wires, which occasioned the most extraordinary noises from the telephones. A perfect storm of foreign sounds made their appearance, and I do not think we could get any speech through while the New York loop was in circuit. I remember also that when this experiment was made we tried the effect of short-circuiting the loop to New York, and at once the articulation of the telephone became audible. Vocal sounds were heard, and the noises due to the loop disappeared. After the conclusion of the experiments of July 12, 1876, I presented the instruments used to Sir William Thomson as a memento of the occasion, and he carried them to England with him.

Int. 145. Please look at the published copy of your lecture delivered before the Society of Telegraph Engineers, October 31, 1877, in London, England, — a like copy of which has been put in evidence by the complainant in this case, — and state whether the instruments which you gave to Sir William Thomson, after the conclusion of your experiments of July 12, 1876, which you have referred to, are correctly pictured therein, and if so, how are the cuts designated?

Ans. Fig. 24 and Fig. 25 represent the instruments which I gave to Sir William Thomson. For convenience of reference, I here insert copies.

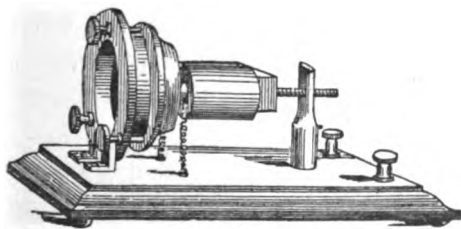


Fig. 24.

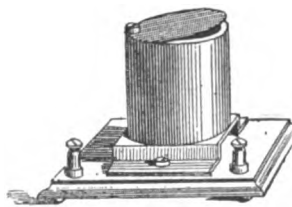


Fig. 25.

These instruments had been pictured in public prints in England before I gave the lecture referred to, and my recollection is that when the Society published my lecture they illustrated my Fig. 24 and Fig. 25 by means of cuts which had been previously used to represent the instruments given to Sir William Thomson. Fig. 24

and Fig. 25, while representing, substantially, the telephones used at the Centennial Exhibition as intended, were not really drawings of those instruments, but of the pair given to Sir William Thomson. In the membrane telephone shown in Fig. 24, the metallic straining-ring and the support for the membrane were similar to the Centennial instruments, and, indeed, were made from the same castings. The double-pole electro-magnet, however, contained coils of very fine wire of great resistance, and was, I think, larger and longer than the double-pole electro-magnet employed at the Centennial. The iron-box receiver shown in Fig. 25 was of greater diameter than the Centennial Iron-Box Receiver it is supposed to illustrate, and differed in some other slight respects. It possesses a peculiar feature that identifies it at once as a picture of the iron-box receiver presented to Sir William Thomson. The iron diaphragm or lid has a small screw at one side fastening it to the edge of the iron box. The Centennial Iron-Box Receiver had no such screw. The instrument used on the 12th of July, 1876, had this feature. The screw was not employed during the course of experiments, but when the instrument was not in use, the diaphragm was screwed to the edge of the iron box so that it should not be lost. At the conclusion of the experiments on July 12, we had no time to pack the telephones for transportation to England. I simply gave them to Sir William, and he said he would put them in his trunk. The diaphragm of the iron-box receiver, not being protected by a packing-case, was probably injured on the voyage, so that upon arrival in England, the iron lid was somewhat distorted, and did not lie down flat on the top of the iron box as it should have done. It was tilted up somewhat, as shown in Fig. 25; and the drawing of Sir William Thomson's instrument can easily be recognized by that tilt.

Int. 146. From your testimony in the last two preceding answers I gather that before you gave the telephones mentioned to Sir William Thomson, you had successfully transmitted and reproduced articulate speech with them; but in order to save any question about it hereafter, I now ask you formally whether such had been the fact?

Ans. Such was the fact. I transmitted and reproduced intelligible speech by means of these instruments before I presented them to Sir William Thomson.

Int. 147. When did you first construct an electro-magnet with permanently-magnetized cores, and use the same in an electric speaking telephone? What was its form of construction, and dimensions, and how was it used?

Ans. I gave orders for the construction of such a telephone in the early part of July, 1876, probably very shortly after my letter of July 2, 1876, to Mr. William Hubbard, which has been quoted in my answer to Interrogatory 136. The apparatus was completed about the middle of July. I fix this date by reference to an entry made in Mr. Charles Williams's account book, on the 15th of July, 1876, giving the charge for making the two-pole electro-magnet with permanently-magnetized cores, employed in the instrument. Mr. Charles Williams is at present abroad, and his books are locked up in a safe to which nobody here seems to have the combination. When I gave my testimony in the *Dowd* suit in 1879, I produced the book, and quoted from it this entry :

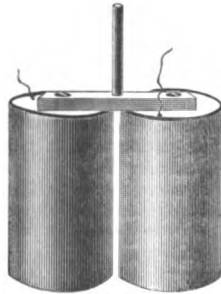
JULY 15, 1876.

A. G. BELL & Co., *Dr.*

To making mag. $3\frac{3}{8}$ in. long of steel, coils of 38 D. C.

Wire, 1740 ohms \$14.75

This electro-magnet with permanently-magnetized cores is still in existence, and was put in evidence in the *Dowd* suit. I here insert a picture of it, reduced in size.



Its dimensions are as follows :

Diameter of spool	.	.	.	.	$1\frac{1}{8}$ inches.
Length of spool	.	.	.	.	3 "
Length of core	.	.	.	.	3 "
Diameter of core	.	.	.	.	$\frac{1}{2}$ "

The length of the cores, with the thickness of the heel-piece added, is $3\frac{3}{8}$ inches, as stated in Mr. Williams's memorandum. This electro-magnet with permanently-magnetized cores was used in a membrane telephone like that given to Sir William Thomson. It was connected in circuit with an iron-box receiver, also like that given to Sir William Thomson. An artificial resistance of great amount was introduced into the circuit, to make the conditions of the experiment similar to those that would have been found upon a real line of great length. No battery was employed. The permanent-magnet telephone was used as a transmitter, and under these circumstances intelligible speech was transmitted, and was reproduced by the iron-box receiver. This experiment was made immediately after the completion of the permanent-magnet telephone; probably about the time that Mr. Williams made the entry in his book — that is, on or about the 15th of July, 1876. I have no doubt, also, that the permanent-magnet telephone was on this occasion, also used as a receiver, and the iron-box instrument as a transmitter, for it was usually my custom to try the reversibility of the instruments. The permanent-magnet telephone was also undoubtedly used in connection with another membrane telephone, instead of the iron-box instrument, and experiments made with it, both as a transmitter and receiver. The electro-magnet with permanently-magnetized cores was also undoubtedly used in connection with the diaphragm of Tagger's iron, described in my answer to Interrogatory 133, and tested both as a transmitter and receiver. Quite a number of experiments were made with that magnet in July, 1876. I cannot now recall the details of all these experiments, but I know that speech sounds were transmitted and received by means of this permanently-magnetized electro-magnet in July, 1876.

Int. 148. At the time when you presented Sir William Thomson with the two telephone instruments you have mentioned and described, what electric speaking telephone instruments had you in your possession at Boston which you can now recall to mind?

Ans. I had duplicates of the instruments given to Sir William Thomson, and a number of experimental membrane telephones. At the time the Centennial membrane telephones were constructed, I had a number of brass castings made of the straining-ring and supporting-

ring. I do not remember how many, but there were certainly not less than half a dozen, probably more. Three of these were used in the construction of the two membrane telephones and the liquid transmitter shown at the Centennial. Two others were employed in the construction of two high-resistance membrane telephones to be used in the proposed experiment between Boston and Philadelphia, and two iron-box receivers were made for that same experiment. I had intended to send one of these membrane telephones and one of the iron-box receivers to Philadelphia to Mr. William Hubbard, and use the other set at the Boston end of the line. At the time, however, when Sir William Thomson was present in Boston, I then knew that the proposed experiment would not be called for by the judges, and so I had no hesitation in giving Sir William Thomson the instruments used in the Equitable Building experiments, as I still had the other pair in my possession. Thus I had left one iron-box receiver, and one high-resistance membrane telephone, and one or more castings of the straining-ring and supporting-ring which were used in the construction of other telephones. In addition to these, I had, I think, some membrane telephones with wooden straining-rings. I also had parts of telephones such as electro-magnets with coils of different resistance which could be placed alternately in the same telephone for the purpose of comparative experiments. I also had a framework or support, to which was attached the diaphragm of Tagger's iron described in my answer to Interrogatory 133, containing also a support for electro-magnets of different kinds, that were experimentally tried in combination with the sheet of Tagger's iron. I cannot pretend to remember all the different electric speaking telephone instruments that I had at the time, and have only mentioned those that occur to me at the present moment.

Int. 149. When, as in your last preceding answer, you make mention of membrane telephones, I suppose you mean magneto telephones having membrane diaphragms, each carrying a patch of iron or steel glued to it as an armature, in the manner of the Centennial magneto telephones with membrane diaphragms. Am I correct?

Ans. Yes. But the patches were not all of the same size or shape as those used in the Centennial instruments. I had a variety

of iron or steel patches of different sizes, from a piece half an inch in diameter up to a sheet of iron or steel almost as large in diameter as the membrane to which it was attached. I do not mean to say that I had a distinct membrane telephone for each size of patch. I was accustomed to take one patch off, and put another patch on the same membrane for the purpose of trying comparative experiments. But all of the membrane telephones were substantially of the same construction as those used at the Centennial.

Int. 150. What is your recollection as to the time when you visited your father's home in Canada, in the summer of 1876, and as to the duration of your stay there?

Ans. I think I went there in the latter part of July, and returned to Boston in the first or second week of September.

Int. 151. I show you a letter, dated August 10, 1876, addressed to you, and signed F. A. P. Barnard. Did you receive it, and if so, when, and who was the writer?

Ans. Yes. I received it very shortly after the date it bears—August 10, 1876. The writer was the President of Columbia College, New York, and was one of the judges at the Centennial Exhibition. He was also one of the editors-in-chief of "Johnson's Illustrated Universal Cyclopedia."

Int. 152. Will you read this letter from President Barnard as part of your present answer?

Ans. The letter is as follows:

INTERNATIONAL EXHIBITION.

1876.

Bureau of Awards.

.....

GROUP.

UNITED STATES CENTENNIAL COMMISSION.

PHILADELPHIA, Aug. 10, 1876.

DEAR SIR:

As a member of the Board of Judges of the Centennial Exhibition for Group XXV., I have been much interested in a report made by Sir William Thomson on your ingenious method of transmitting vocal sounds by telegraph. My engagements were, unfortunately, such as to put it out of my power to attend, in Philadelphia, during the month of June, and I therefore was not present when the examination of your apparatus was made by the committee of the Board.

I have now in press a work of which the enclosed circular will give you some idea, in the progress of which we have just reached the word Telegraph, and the galley proof of the article on that subject has just reached me.

I am exceedingly desirous to add to this article some brief notice of your very remarkable invention, and I write to you in the hope that you may find it convenient to furnish me with a paragraph giving a popular account of it, in time for insertion in its proper place.

I might, it is true, make an abstract of Sir Wm. Thomson's still unpublished report, to which I have access, but I would rather the statement should be made by yourself. It will be in season if received within the next ten days, but it is, of course, desirable that as little time should be lost as possible.

May I hope to have the pleasure of hearing from you at your early convenience?

I have left Phila. for Saratoga where I shall remain for a week or two. I stop at a private house. *My address is Saratoga* simply.

Sincerely yours,

F. A. P. BARNARD.

PROFESSOR A. GRAHAM BELL.

Int. 153. To what work did the circular enclosed with this letter relate, and did you write for it any article, in compliance with the invitation of President Barnard?

Ans. The enclosed circular related to "Johnson's Illustrated Universal Cyclopedia." I did not write for it.

Int. 154. If any notable events in the history of your electric speaking telephone occurred during your sojourn in Canada, in August, 1876, will you briefly mention them?

Ans. In the first week in August, 1876, I made the experiment of transmitting the voices of three persons simultaneously along the line. I had a triple mouth-piece made for one of my membrane telephones, and this was placed in one of the outbuildings on my father's place at Tutelo Heights, near Brantford. The iron-box receiver was placed upon the veranda of the house. Three persons spoke and sang simultaneously into the triple mouth-piece, and the three voices — words and all — were reproduced by the iron or steel diaphragm of the iron-box receiver. I may be mistaken as to the location of the instruments, but, at all events, one, either the transmitter or the receiver, was on the veranda of my father's house, and the other in one of the outbuildings.

Subsequently to this experiment, but during the first or second week in August, 1876, another notable event in the history of the electric speaking telephone occurred. Articulate speech was, for the first time, transmitted and received between places that were separated by miles of space. I recall three experiments that were made in Canada, during the first two weeks of August, 1876. In all three of these experiments a membrane telephone was used as a transmitter, and the iron-box telephone as a receiver; and the membrane telephone was located in the office of the Dominion Telegraph Company, in Brantford, Ontario. The iron-box receiver was, in one experiment, located in the town of Paris, about eight miles from Brantford, the battery, however, being in Toronto, a distance of 68 miles from Paris. In another experiment the receiver was in Mount Pleasant; about five miles from Brantford; and in the third experiment, the receiver was placed on the veranda of my father's house at Tutelo Heights, a distance, I suppose, of three or perhaps four miles from Brantford.

In the first experiment alluded to, the membrane telephone with triple mouth-piece was placed in the Dominion Telegraph Company's office in Brantford, under the charge of Mr. Griffin, who was, if I remember rightly, either the manager or operator there. As my father told me he would be unable to be present on account of an engagement, I made arrangements with my uncle, Professor David C. Bell, to go to the Dominion office at an appointed hour, and recite into the membrane telephone. I also requested him to provide some singers, who should sing a three-part song into the triple mouth-piece. I then drove to the town of Paris—eight miles from Brantford—and attached the iron-box receiver to one of the lines leading to Brantford. The battery that operated the instruments was—as I have already said—in Toronto. I had provided electro-magnets having coils of different resistance, which could be interchangeably used in the telephones employed. Low-resistance coils were first tried. The moment I placed my ear against the diaphragm of the iron-box receiver, I heard bubbling and crackling sounds, similar to those I had observed on the New York loop experiment, made July 12, 1876, on the lines of the Atlantic & Pacific Telegraph Company. Mixed up with this storm of noises, I could plainly perceive the

voices of the speakers and singers in Brantford, in a faint, far-away sort of manner. I then telegraphed to Brantford by another line; and asked Mr. Griffin to substitute an electro-magnet with coils of high resistance for the low-resistance one he had been using. While he was doing this I made a similar change in the coil of the iron-box receiver. The experiments were then resumed. The disturbing noises still continued, but the vocal sounds, in place of being faint and far away, became so loud and clear that familiar sentences were understood, and I could even recognize the voices of the different speakers and singers. One voice sounded so like my father's that I telegraphed to Brantford to ascertain whether it could possibly be his, for I had understood that he could not be present at the time. He was there, however, and it was his voice that I had heard.

It will be understood that in these experiments the listener was in Paris, Ontario; the speakers were in Brantford, Ontario, eight miles from Paris; and the battery in Toronto, 68 miles from Paris. This, I believe, was the first time words and sentences spoken in one place were transmitted by electrical means and successfully reproduced in another place many miles away. The experiment, I think, was made in the second week in August, 1876; probably on the 10th of that month.

One of the lines of the Dominion Telegraph Company led to Mount Pleasant, passing within about a quarter of a mile of my father's house. My father had arranged for a public reception at his house, and I was anxious to exhibit the speaking telephone in operation upon that occasion. I took my receiving-instrument to Mount Pleasant for the purpose of testing that wire, as the manager of the Dominion Telegraph Company had kindly offered me the use of the wire upon the occasion of the reception at my father's house, if it would be suitable for the purposes of my experiment. The membrane telephone was operated in Brantford, and I listened to the iron-box receiver in the telegraph office at Mount Pleasant. Similar results were obtained to those noted for the Paris experiment. I therefore decided to use this wire. In order to connect it with my father's house, I purchased, in the town of Brantford, a lot of common iron wire, such as is commonly employed in supporting stove-pipe. It was, of course, not insulated. I tacked this stove-pipe wire on the

wooden fences by the roadside, so as to connect my father's house at Tutelo Heights with the Dominion telegraph line on the Mount Pleasant road, about a quarter of a mile away. The line to Mount Pleasant was cut, and communication established with Brantford through the stove-pipe wire, a ground having been made at my father's house. Experiments similar to those made between Brantford and Paris were repeated for the information of the guests, and the results were witnessed by quite a large number of persons.

Int. 155. Was any notice of your experiments in Canada, to which you have referred in your last preceding answer, published in the United States, and if so, when, and in what periodical?

Ans. Yes. A notice of these experiments appeared in the *Scientific American* of September 9, 1876, in an article entitled, "The Human Voice Transmitted by Telegraph." I cut out the article at the time, and preserved it in a scrapbook, which is now before me.

[*Counsel for defendants puts in evidence a copy of the article referred to, and it is marked "Defendants' Exhibit Scientific American Article of September 9, 1876, H. L. H., Special Examiner."*]

Int. 156. From what should you judge the description of your telephones, contained in this *Scientific American* article of September 9, 1876, preceding the reference to your Canada experiments, was taken; and how do the dates and sequence of events stated for your Canada experiments compare with your remembrance of them?

Ans. The language used in describing my telephones, following the words "The apparatus used by Professor Bell is thus described," very closely resembles the language of the article published in the *Boston Evening Transcript*, May 31, 1876, giving an account of my address before the Society of Arts on the 25th of May, 1876, at the Massachusetts Institute of Technology. The language used before the sentence I have quoted does not seem to have been derived from anything that I had written or said. The latter part of the article, giving an account of the Canadian experiments, I think is substantially correct. At least, the facts are correct; I am not so sure about the precise dates. I am inclined to think that the account of the meeting on the evening of August 12 referred to the public exhibition I had given to the guests at my father's house,

in Canada. I am also inclined to think that the experiment referred to as having been made on August 10 was the experiment between Brantford and Paris, which was an important and noteworthy one, although an experiment between Brantford and Mount Pleasant *was* made somewhere about that date. This latter was a very short experiment, simply to see whether the wire would be used, and I am a little uncertain about its date. I am very much inclined to think it was on the day preceding the reception. The experiments described as having been made on August the 11th, in which instruments were placed, one in the porch of the residence, and the other in an outhouse on the grounds, were probably made on the day specified, but not for the first time. The instruments were arranged as described, with a triple mouth-piece, and three voices were transmitted simultaneously during the first week in August. The experiments were repeated a number of times, at subsequent dates, for the information of visitors to my father's house.

Int. 157. When did you resume your electrical experiments in Boston, after your summer vacation in 1876, and if any special arrangement was made to facilitate your electrical researches, what was it?

Ans. I resumed electrical experiments in Boston somewhere about the 11th of September, 1876, at which time an arrangement was made with Mr. Thomas A. Watson, whereby he should devote half of his time to my experiments, under my own personal supervision, receiving payment therefor from me and my associates, Messrs. Sanders and Hubbard. Before this time, Mr. Watson had been exclusively in the employment of Mr. Williams, and had been paid by him, although he had been specially assigned to my work. About the 11th of September he was employed and paid by us for a portion of his time, and given an interest in the inventions he was assisting me to put into commercial use.

Int. 158. What was the character of the electrical work upon which you were principally engaged during the remainder of September, 1876?

Ans. It related principally to multiple telegraphy. At that time the pecuniary value of the speaking telephone inventions was not fully appreciated, although the invention was looked upon as a very

wonderful thing; and my associates, Messrs. Sanders and Hubbard, were anxious that considerable attention should be devoted also to the multiple-telegraph inventions which had been somewhat neglected.

Int. 159. It has already appeared in evidence that on September 14, 1876, there was published in *Nature*, a scientific periodical of London, England, an account of the meeting of the British Association at Glasgow, Scotland, and, among other things, the opening address by Professor Sir William Thomson, the president of the mathematical and physical section. Was a part of that address republished in the United States, and if so, where did it appear, and did you preserve a copy of it at the time?

Ans. Yes. A passage from the opening address of Sir William Thomson was published in the *Boston Daily Advertiser* of September 25, 1876. I cut out the article at the time, and preserved it in a scrapbook which is now before me.

[*Counsel for defendants puts in evidence a copy of the article just referred to, and it is marked "Defendants' Exhibit Boston Advertiser Article of September 25. 1876, H. L. H., Special Examiner."*]

Int. 161. Will you quote from *Nature* of September 14, 1876, which I have here present, all that part of Sir William Thomson's address referred to, which relates to telegraphic matters?

Ans. I will. It is as follows:

"In the United States telegraphic department I saw and heard Elisha Gray's splendidly worked-out electric telephone actually sounding four messages simultaneously on the Morse code, and clearly capable of doing yet four times as many with very moderate improvements of detail; and I saw Edison's automatic telegraph delivering 1015 words in 57 seconds: this done by the long neglected electrochemical method of Bain, long ago condemned in England to the helot work of recording from a relay, and then turned adrift as needlessly delicate for that. In the Canadian department I heard "To be or not to be, . . . there's the rub," through an electric telegraph wire; but, scorning monosyllables, the electric articulation rose to higher flights, and gave me messages taken at random from the New York newspapers — 'S. S. Cox has arrived' (I failed to make out the S. S. Cox); 'The City of New York,' 'Senator Morton,' 'The Senate has resolved to print a thousand extra copies'; 'The Americans in London have resolved to celebrate the coming 4th of July.' All this my own ears heard, spoken to me with unmistakable distinctness by the thin circular

disc armature of just such another little electro-magnet as this which I hold in my hand. The words were shouted with a clear and loud voice by my colleague-judge, Professor Watson, at the far end of the telegraph wire, holding his mouth close to a stretched membrane, such as you see before you here, carrying a little piece of soft iron, which was thus made to perform in the neighborhood of an electro-magnet in circuit with the line motions proportional to the sonoric motions of the air. This, the greatest by far of all the marvels of the electric telegraph, is due to a young countryman of our own, Mr. Graham Bell, of Edinburg and Montreal, and Boston, now becoming a naturalized citizen of the United States. Who can but admire the hardihood of invention which devised such very slight means to realize the mathematical conception that, if electricity is to convey all the delicacies of quality which distinguish articulate speech, the strength of its current must vary continuously and as nearly as may be in simple proportion to the velocity of a particle of air engaged in constituting the sound?"

Int. 162. Did you receive a Certificate of Award for your electric telephone and multiple telegraph, and if so, when was it dated, and if you have a copy of it, please read it as a part of your answer.

Ans. I did receive a Certificate of Award. It was dated September 27, 1876, and was as follows :

INTERNATIONAL EXHIBITION.

1876.

CERTIFICATE OF AWARD.

ALEXANDER GRAHAM BELL,

Salem, Mass.

Graham Bell's Electric Telephone and Multiple Telegraph.

No. 3. Group XXV.

UNITED STATES CENTENNIAL COMMISSION.

(In accordance with the Act of Congress.)

Philadelphia, September 27th, 1876.

A. T. GOSHORN, *Director General.*

JOHN L. CAMPBELL, *Secretary.* JOSEPH R. HAWLEY, *President.*

Int. 163. When did you begin to carry forward your experiments with the electric speaking telephone beyond the point where you had left it in July, 1876, when you took your summer vacation; and what was the next important stage of its development?

Ans. About the first of October, 1876, I began to devote my attention mainly to the speaking telephone, subordinating multiple telegraphy. I commenced making a theoretical study of the operation of magneto telephones for the purpose of arriving theoretically at the best arrangements upon long lines; and I discussed with Mr. Watson the results of the experiments we had made in July, 1876, so that we might carry them on beyond the point reached at the time when my July experiments were interrupted by my visit to Canada. In July, 1876, we had made iron patches of different sizes which were used comparatively in the construction of membrane telephones. The general results of the experiments had been that the larger the iron patch upon the membrane of the telephone, the louder and more distinct had been the articulation. We had experimented in July, 1876, with sheets of iron almost as large in diameter as the membrane to which they were attached, and I had proposed, at this time — July, 1876 — to adopt a diaphragm of Tagger's iron in place of the membrane and attached patch. When I took up the subject again in the beginning of October, 1876, I determined to repeat the experiments with membrane telephones, each carrying a sheet of iron almost as large in diameter as the membrane to which it was attached, and to construct and test telephones with metallic diaphragms alone. In accordance with this decision, Mr. Watson arranged two single-pole electro-magnet membrane telephones with straining-rings and supporting-rings made of castings from the same patterns as those of the Centennial membrane telephones, and upon each membrane he glued a thin, circular sheet of iron, almost as large in diameter as the membrane itself. No mouth-piece was employed, and the electro-magnet was presented to the opposite side of the membrane to that shown in the Centennial instruments, and with its pole next the membrane inside the supporting-ring. By this arrangement, the ear could be brought into close contact with the iron disk, the membrane being between it and the pole of the magnet. The ear could be pressed against the sheet of iron in the way we had been accustomed to do with the lid of the iron-box receiver. The mouth also could be brought into close proximity to the iron disk when we used the instrument as a transmitter. Two telephones so constructed were arranged in different rooms connected with my laboratory at No. 5

Exeter Place, Boston, in circuit with a battery. Mr. Watson was at one end of the circuit, and I at the other. Upon testing the instruments, we found no difficulty in carrying on a sustained conversation through the circuit by means of the telephones. We then determined to test the instruments upon a real line. I think it was on the evening of the same day that we tried them upon a line owned by the Walworth Manufacturing Company, and extending from their office in Boston to their factory in Cambridgeport, a distance of about two miles. The experiment upon this line took place on the evening of October 9, 1876. I was at the Boston end of the line, and Mr. Watson was in Cambridgeport. The results were very satisfactory, and sustained conversation was, for the first time, carried on by electrical means between persons who were miles apart. In the former experiments in Canada, the transmission of speech had been made only one way, communication in the other direction being carried on by telegraphic means, upon another line. But in this experiment, made on the 9th of October, 1876, actual conversation, backwards and forwards, upon the same line, and by the same instruments reciprocally used, was successfully carried on for the first time upon a real line of miles in length.

In order to test the accuracy of transmission, Mr. Watson and I each made a record of the words transmitted and received, so that the two records could afterwards be compared, and the accuracy of transmission ascertained. These two records were published, in parallel columns, in the *Boston Daily Advertiser* of October 19, 1876, a copy of which is before me.

[*Counsel for defendants puts in evidence a copy of the newspaper article just referred to by the witness, and it is marked "Defendants' Exhibit Boston Advertiser Article of October 19, 1876, H. L. H., Special Examiner."*] *

Int. 164. Did you make public exhibition of these same telephones shortly after their trial upon the telegraph line of the Wal-

* The article is headed "Telephony. Audible Speech Conveyed Two Miles by Telegraph." It is an account of the transmission of speech between Boston and Cambridgeport, and gives, in parallel columns, what was said at one end of the line and what was heard at the other. It shows that most of the conversation was transmitted with substantial accuracy.

worth Manufacturing Company; if so, when, and what newspaper notice appeared in relation to it?

Ans. On Wednesday, the 11th of October, two days after the experiment upon the line of the Walworth Manufacturing Company, I communicated the results of the experiment to the American Academy of Arts and Sciences, and exhibited in operation the telephones that had been employed. These were tested by a number of the members, and the congratulations of the Academy were tendered me upon my success.

This meeting was noticed in the *Boston Daily Advertiser* on Saturday, October 14, 1876, and I cut out the item from the paper, and pasted it in my scrap-book, and I have it now before me. From this notice I read as follows:

“At a meeting of the American Academy on Wednesday night, Professor Bell exhibited his wonderful discovery by which sounds may be transmitted through wires by means of the electric current. By the invention of peculiar apparatus, conversation may be carried on through hundreds of miles of wires with the greatest ease.”

Int. 165. In your answer to Interrogatory 133, when describing the diaphragm of Tagger's iron attached to a metallic rim which carried three metallic rods, you did not specify the relative thickness of such sheet of iron. Will you here state that particular?

Ans. Tagger's iron could be obtained in very thin sheets, almost as thin as the membranes that were employed in my telephones. The specimen referred to was pretty thin; I do not now remember whether it was the thinnest that could be obtained, or not.

Int. 166. You have mentioned your intention, about the first of October, 1876, of dispensing with membrane diaphragms in your telephones, and substituting therein thin iron diaphragms alone. When did you carry this intention into effect, and what was the construction of the instruments?

Ans. If I remember correctly, we tried this almost immediately after the Walworth line experiments. Within a few days after that, we were using sheets of iron or steel of sufficient thickness to support their own weight when held horizontally by one edge. As no supporting or straining-rings were used, it was only necessary to hold or fasten the sheet of iron or steel in any convenient manner,

with its surface in close proximity to the pole of the electro-magnet. Apparatus arranged in this way was found to work well, both as a transmitter and a receiver, and the articulation produced by the metallic diaphragm was more distinct than when a membrane diaphragm was employed.

About the 19th or 20th of October, box telephones were constructed, each containing a single-pole electro-magnet. A sheet of iron or steel formed one side of the box, and the electro-magnet inside was arranged with its pole in close proximity to the centre of the metallic diaphragm. Each box was rectangular in shape, and at first was provided with a hole on the top, into which we spoke. Comparative experiments, however, soon demonstrated the fact that the clearest and best articulation was obtained by placing the mouth against the iron or steel diaphragm, and covering the mouth with the hand and that the hole at the top of the box was an actual disadvantage. Each instrument we operated both as transmitter and receiver. In transmitting speech, the mouth was placed against the steel plate and covered with the hand. In receiving speech, the ear was pressed into contact with the plate.

Int. 167. Did you make any special arrangements to enable you to carry on experiments with these box telephones, provided with diaphragms of thin sheets of iron or steel, and to ascertain their adaptability for use upon long, out-of-door lines; and, if so, what, and when?

Ans. Yes. As all my experiments had relation to the commercial use of the telephones upon long lines, I thought it would be a good plan for me to have a real line connected with my laboratory, rather than simply to imitate the conditions of a real line by the use of artificial resistances. I was in the habit of going out to Mr. Gardiner G. Hubbard's house in Cambridge very frequently in the evening; and as this was not far from the Cambridge observatory, it occurred to me that it would be a good plan to make arrangements to have the use of the Cambridge time-line for experimental purposes. This line connected Cambridge observatory with Boston, and during the day-time it was employed in transmitting time to various places in Boston; signals being sent from the Cambridge observatory clock, by means of which clocks in Boston were regu-

lated. The wire was not required for this purpose at night, as a general rule, and I was fortunate enough to make arrangements with Professor Rogers, of the observatory, whereby I could have the use of the line in the evening, after the stores had closed. This line came to the office of George & Stearns, electricians, at No. 39 Pearl Street, where it was connected, as required, with various clockmakers' establishments in Boston. In order to take advantage of Professor Rogers's invitation, I had a permanent line run between my laboratory in Exeter Place and the office of George & Stearns, in Pearl Street. In the evening, when desired, this line could be connected with Cambridge observatory. This line was completed on Friday morning, the 10th of November, 1876. Conversation was carried on through it on that morning by means of the box telephones I have described; and after this date, the line was frequently connected with Cambridge, and conversation carried on telephonically between Mr. Watson in Boston, and myself in Cambridge observatory. The distance between these two places I should think was between four and five miles.

It was my custom, when some new modification had been made, to carry out a telephone to Cambridge, and test it, at night, on the line running to the laboratory, Mr. Watson being at the Boston end.

[*Counsel for defendants, in view of the objection taken by counsel for complainant on December 1, 1891, that the "Exhibit Bell's British Telephone Patent" then put in evidence was not offered in the proper order, again formally puts in evidence the officially printed provisional specification filed in the British Patent Office December 9, 1876, by William Morgan-Brown as a communication from Alexander Graham Bell.*]

Int. 168. When was the provisional specification for your British Patent No. 4765, of December 9, 1876, prepared and completed, ready to be sent to England to be there duly engrossed and filed?

Ans. It was prepared in October, 1876, and completed in the early part of November, 1876. I remember specially that I was very busy upon the subject during Mr. Watson's absence at the Centennial Exhibition, the latter part of October.

Int. 169. That provisional specification contained, among other things, the following paragraphs:

"The fifth part of the invention relates to the electrical production or transmission of sounds of every kind, without a battery, by means of undulatory currents of electricity, whereby not only musical notes but articulate speech can be transmitted over a telegraph line, and two or more messages be sent simultaneously over a single circuit, in the same or in opposite directions. . . .

In the fifth plan of the invention illustrated in Figures 24, 25, and 26 the battery is omitted and a permanent magnet M^3 is substituted for the soft iron core of the electro magnets used in the other telephones. Or the coils shown in Figures 24, 25, and 26 may be induction coils of usual construction, local batteries being placed in circuit with the primary wires so as to magnetize the soft iron cores of the coils. The undulations induced in the secondary wires by the vibration of the plates A^3 being directed upon the line wire."

You have already called attention to the fact that on July 2, 1876, you wrote to Mr. William H. Hubbard, in relation to your telephones with high-resistance coils, the following :

"I am sure by substituting a permanent magnet for the pole of the electro-magnet, I could work it without a battery at all."

And you have described a double-pole electro-magnet having permanently-magnetized cores, which was made on or about July 15, 1876, and immediately tried by you in various ways. What further use of electro-magnets with permanently-magnetized cores did you make in your electric speaking telephones, and what circumstance particularly started you towards their adoption?

Ans. The experiments made in July, 1876, with the electro-magnet having permanently-magnetized cores, upon circuits containing artificial resistances of great amount, convinced me that the statement you have quoted from my letter to Mr. William Hubbard, of July 2, 1876, was correct, and that I could work my telephone upon long lines without a battery, by substituting a permanent magnet for the pole of the electro-magnet. I do not think, however, that I had the opportunity of testing this matter upon a real line in July, 1876. Within a day or two after the completion of the line connecting my laboratory in Exeter Place with the office of George & Stearns, that is, within a day or two after the 10th of November, 1876, I tried the experiment between Boston and the Cambridge observatory ; employing upon the occasion the same electro-magnet with permanently-magnetized cores which had been made for me by

Mr. Charles Williams, on or about the 15th of July, 1876. The telephone containing this electro-magnet was at the Boston end of the line, and was operated successfully without any battery upon the circuit, both as a transmitter and receiver for articulate speech. This experiment not only satisfied me that permanent-magnet telephones working without a battery could be used on long lines, but that they had an actual advantage over telephones containing electro-magnets operated by a battery current on the main line when lines of great resistance were employed. In order to make my meaning clear, I may say, that when a powerful battery current passed through the coil of an electro-magnet upon a short circuit, the magnetical condition of the iron core I believed to be greater than if the core had been permanently magnetized, without any battery on the circuit; and I therefore believed that electro-magnets worked by battery currents would produce more powerful audible effects in speaking telephones operating on a short circuit, than electro-magnets having permanently-magnetized cores and operated without any battery upon the circuit. The experiments on the Cambridge observatory line, however, made shortly after the 10th of November, 1876, convinced me that the conditions were very different upon a real line of considerable resistance. When I came to think the matter over, I saw that where a battery current was employed upon the main line, the magnetic condition of the iron core of an electro-magnet upon the circuit would become less and less with every increase in the resistance of the line; the strength of the current upon the line becoming weaker as the line was increased in length, so that upon long lines of very great resistance it would be difficult by means of a battery upon the line to produce in the core of the electro-magnet upon the circuit a magnetic condition comparable to that of a permanently-magnetized core. I further saw, that even if it were possible, by means of a very large and powerful battery, to produce in the core of an electro-magnet upon a long line a magnetical condition equal to that of a permanently-magnetized core without any battery upon the line, still the permanently-magnetized core would have an advantage over the other, on the ground of simplicity and economy of operation. I still further saw, that even if it were possible, by means of a powerful battery on the main line, to produce a magnet

ical condition greater than that of a permanently-magnetized core without any battery upon the circuit, a still greater magnetic condition could be produced by a very much smaller and less expensive battery in a local circuit, independent of the main line. This idea will be understood by reference to the second paragraph, quoted in the question, from the provisional specification of my British patent, where I say, that the coils of the telephones shown in Figs. 24, 25 and 26 "may be induction coils of usual construction, local batteries being placed in circuit with the primary wires so as to magnetize the soft-iron cores of the coils; the undulations induced in the secondary wires by the vibration of the plates A³ being directed upon the line wire."

It seemed to me that either by the employment of a permanently-magnetized core, or by the use of a local battery and coil, independent of the main circuit, to magnetize a soft-iron core, the magnetical condition of the core could be maintained at a constant state, uninfluenced by the resistance of the main circuit. In this way, a powerful magnetic condition could be maintained upon lines of great length, and the magneto telephone be operated economically on such lines without any battery upon the main circuit.

Int. 170. You have referred to the employment of the electro-magnet with permanently-magnetized cores made in July, upon the Cambridge observatory line a day or two after November 10, 1876, and have stated that such electro-magnet was used in a telephone at the Boston end of the line to transmit and receive articulate speech. In that experiment, what energized the telephone at the Cambridge end of the line?

Ans. I do not now remember the construction of the instrument used at the Cambridge end of the line. It may, perhaps, also have had permanently-magnetized core, or cores, but I cannot be sure of this. I am inclined to think that it had soft-iron cores, in which case it operated by virtue of residual magnetism — that is, the core, or cores, were, in reality, weak, permanent magnets.

Int. 171. Did you have an opportunity to try your electric speaking telephones upon a still longer line than that running between Boston and the Cambridge observatory, and if so, when next, and what public notice of it was taken?

Ans. Yes. I made experiments on the wires of the Eastern

Railroad Company on Sunday, November 26, 1876. Upon this occasion, conversation was carried on *viva voce* between persons in Boston and Salem.

An account of the experiments appeared next morning, November 27, 1876, in the *Boston Post*, *Boston Daily Globe*, *Boston Daily Advertiser*, and *Boston Herald*. I cut the items out at the time, and preserved them in my scrap-book, which is now before me. The following is the account published in the *Boston Post* on Monday morning, November 27, 1876:

"ELECTRIC TELEPHONY.

Some More Satisfactory Experiments by Professor A. Graham Bell — Sending Vocal Sounds 200 Miles.

The experiments in electric telephony, which Professor A. Graham Bell has been conducting for several years past, have resulted in the development of apparatus by means of which the human voice, as ordinarily used in speaking, can be transmitted with certainty and ease to an indefinite distance — assuredly hundreds of miles. The contrivance is exceedingly simple, and the expense is considerably less than the cost of an ordinary Morse Sounder. The application of this discovery promises to completely revolutionize the business of transmitting messages by electricity between distant points.

The latest experiments with the telephone were made yesterday over the wires of the Eastern Railroad, that day being selected because the trials would not then be interrupted by the ordinary business of the line. Professor Bell, President Rockwell of the Eastern road, and wife, Miss Stearns, Mr. Morrison and Mr. Hubbard, besides two telegraph operators, were the occupants of the Boston office. The instruments were arranged for about a twenty-mile test, consequently, Salem, about sixteen miles away, was the point at which a second telephone was fixed. Mr. Thomas A. Watson, assisted by the Salem operator, was in charge there. All those at the Boston end of the line held free and easy conversation with the Salem office, even a whisper or a loud breath being distinctly heard at either end when given at the other. A remarkable instance of the extreme delicacy and faithfulness of the instrument was shown in the fact that when Mr. Hubbard first addressed the listener at the Salem end of the line, Mr. Watson instantly recognized his voice and called him by name before replying. Instead of grounding the wire at Salem that office was made a way-station, the through line extending to North Conway, 143 miles away. To give a more exacting test the Boston instrument was then attached to the Portland wire and the circuit made complete from Boston, through that city to Salem, a distance of about 200 miles. The voice could be heard

with considerable clearness after having passed over this great distance, but owing to the unfit construction of the telephones for the duty required of them (they being arranged for about twenty miles), a distinctness was not attained which would allow a conversation to be carried on. Professor Bell is continually improving his invention, and he doubts not that he will ultimately be able to chat pleasantly with friends in Europe while sitting comfortably in his Boston home."

Int. 172. Were the statements contained in the article from the *Boston Post* of November 27, 1876, which you read in your answer to the last preceding interrogatory, substantially correct in respect to the experiments referred to?

Ans. I think they were substantially correct. At all events they agree very well with my present recollection of the experiments.

Int. 173. What sort of diaphragms did your electric speaking telephones have which were used upon that occasion?

Ans. I think they were metallic diaphragms of iron or steel.

Int. 174. When did you adopt the use of electro-magnets with permanently-magnetized cores for use in your electric speaking telephones, to the exclusion, for practical purposes, of electro-magnets with soft-iron cores magnetized by a battery upon the main line?

Ans. About the first of December, 1876.

Int. 175. When were the next experiments made with your electric speaking telephones upon a long line, after those of Sunday, November 26, 1876, and who conducted them?

Ans. The next experiments were made upon the following Sunday, December 3, 1876, upon the lines of the Eastern Railroad Company, between Boston and North Conway, N. H. The experiments were conducted by Mr. Thomas A. Watson and myself. I was in Boston, and Mr. Watson in North Conway.

Int. 176. What, in general terms, was the character of your experiments in December, 1876, and how far did they progress?

Ans. A multitude of experiments were made in December, 1876, with the object of ascertaining empirically the best arrangement of permanent magnet, plate-armature, coil and mouth-piece for use upon long lines. For this purpose I would keep every element of my

combination constant excepting one, and test the effect of variations of that element. For example, using a given permanent magnet and a given coil, I would try the effect of iron and steel plates of different diameters and thicknesses. Again, using a given permanent magnet and a given plate-armature, I would vary the coil; and using a given coil and a given plate I would vary the permanent magnet employed. Having in this way obtained an idea of the best form of each element, I sought to combine these in a practical working telephone, also experimenting upon the best form of mouth-piece.

The extent to which I had progressed in December, 1876, is shown by my patent No. 186,787, of January 30, 1876. All the improvements shown in that patent had been arrived at before I left for Canada in December, 1876.

Int. 177. When did you make your visit to your father's home, at Brantford, Canada, in December, 1876, and how long did you remain there?

Ans. I arrived in Brantford on the 23d of December, 1876, and left Brantford on the 26th of December, 1876.

Int. 178. You have testified that you began your testimony in the *Harmonic Telegraph Interferences* in Washington, D. C., on January 2, 1877. That day was just one week from December 26, 1876, when you left Brantford, Canada. State, as well as you recollect, where you were during that week.

Ans. My recollection is that I left Brantford for Washington on the 26th of December, 1876, stopping off at Boston on the way. How long I remained in Boston I cannot now remember; but I am inclined to think that I must have been in Washington before the 2d of January, in order to prepare myself for my examination in the *Harmonic Telegraph Interferences* by conference with my counsel. If I remember rightly it took about twenty-four hours to go from Brantford to Boston. This is as nearly as I can account for my time at the present date.

Int. 179. Have you in your possession the original award made by Sir William Thomson, relating to your electrical exhibit at the Centennial Exhibition, and if so, will you produce a copy of it?

Ans. I have in my possession the original award sent to me by

the judges of the Centennial Exhibition, dated December 26, 1876, and I produce a copy of it.

[*Counsel for defendants put in evidence the copy of the award just referred to, and it is marked "Defendants' Exhibit Bell's Centennial Award, H. L. H., Special Examiner."**

Counsel for defendants also puts in evidence so much of the "General Report of the judges of group XXV." as was made by Joseph Henry, LL. D., under the general head of "Electrical Apparatus" upon "The Electric Telephone and Multiple Telegraph," the same

* The Centennial award to Mr. Bell begins with the statement that the commission has examined the report of the judges, and accepted the following reasons, and decreed the award in conformity therewith. Then follows the "Report on Awards," signed by Sir William Thomson (afterwards Lord Kelvin). The report describes Mr. Bell's multiple telegraph, which it calls the "electro-phonetic multiple telegraph," and then the writer reports on the telephone as follows:

"In addition to his electro-phonetic multiple telegraph, Mr. Graham Bell exhibits apparatus by which he has achieved a result of transcendent scientific interest,—the transmission of spoken words by electric currents through a telegraph wire. To obtain this result, or even to make a first step towards it,—the transmission of different qualities of sound, such as the vowel sounds,—Mr. Bell perceived that he must produce a variation of strength of current in the telegraph wire as nearly as may be in exact proportion to the velocity of a particle of air moved by the sound; and he invented a method of doing so, a piece of iron attached to a membrane, and thus moved to and fro in the neighborhood of an electro-magnet, which has proved perfectly successful. The battery and wire of this electro-magnet are in circuit with the telegraph wire and wire of another electro-magnet at the receiving station. This second electro-magnet has a solid bar of iron for core, which is connected at one end, by a thick disc of iron, to an iron tube surrounding the coil and bar. The free circular end of the tube constitutes one pole of the electro-magnet, and the adjacent free end of the bar-core the other. A thin, circular iron disc, held pressed against the end of the tube by the electro-magnet attraction, and free to vibrate through a very small space without touching the central pole, constitutes the sounder by which the electric effect is reconverted into sound. With my ear pressed against this disc I heard it speak distinctly several sentences, first of simple monosyllables, 'To be or not to be' (marvellously distinct); afterwards sentences from a newspaper, 'S. S. Cox has arrived' (I failed to hear the 'S. S. Cox,' but the 'has arrived' I heard with perfect distinctness; then 'City of New York,' 'Senator Morton,' 'The Senate has passed a resolution to print one thousand extra copies,' 'The Americans of London have made arrangements to celebrate the Fourth of July.' I need scarcely say I was astonished and delighted; so were others, including some other Judges of our Group, who witnessed the experiments and verified with their own ears the electric transmission of speech. This, perhaps the greatest marvel hitherto achieved by the electric telegraph, has been obtained by appliances of quite a homespun and rudimentary character. With somewhat more advanced plans, and more powerful apparatus, we may confidently expect that Mr. Bell will give us the means of making voice and spoken words audible through the electric wire to an ear hundreds of miles distant.

WILLIAM THOMSON,
Signature of the Judge.

Approval of Group Judges.

J. E. Hilgard.
James C. Watson.
H. K. Oliver.
F. A. P. Barnard.
J. Schudmayer.

E. Levasseur.
P. F. Kupka.
Ed. Favre Perret.
Chas. E. Emery.
Joseph Henry."

being contained in a printed publication, the title page of which is as follows :

UNITED STATES CENTENNIAL COMMISSION.

INTERNATIONAL EXHIBITION,
1876.

REPORTS AND AWARDS
Vol. VII.
Groups XXI-XXVII.

Edited by
FRANCIS A. WALKER,
Chief of the Bureau of Awards.

Washington :
Government Printing Office.
1880.

*A copy of the report here put in evidence is marked " Defendants' Exhibit Professor Henry's Centennial Report, H. L. H., Special Examiner."]**

* Professor Henry's report first considers the multiple telegraph, and then proceeds as follows :

"The telephone of Mr. Bell aims at a still more remarkable result, — that of transmitting audible speech through long telegraphic lines. In the improved instrument the result is produced with striking effect, without the employment of an electrical current other than that produced by the mechanical action of the impulse of the breath as it issues from the lungs in producing articulate sounds. To understand this wonderful result, suppose a plate of sheet-iron, about five inches square, suspended vertically before the mouth of the speaker so as to vibrate freely by the motion of the air due to the speech, and suppose also another iron plate, of the like dimensions, similarly suspended before the ear of the hearer of the sound, and between these, but not in contact with them, is stretched the long telegraphic wire. Each end of this wire is attached to two coils of insulated wire surrounding a core of soft iron, the ends of which are placed near the middle of the plate, but not in contact with it. These four cores are kept in a magnetic condition by being attached at each end of the line to the two poles of a permanent magnet. Now it is evident that in this arrangement any disturbance of the magnetism of one of the permanent magnets increasing or diminishing it will induce electrical currents, which, traversing the long wire, will produce a similar disturbance of the magnetism of the arrangement at the other end of the wire. Such a disturbance will be produced by the vibration of the plate of soft iron due to the words of the speaker, and the current thus produced, changing the magnetism of the soft-iron cores, will by reaction produce corresponding vibrations in the iron plate suspended before the ear of the hearer. The vibrations of the second plate being similar to those of the first will reproduce the same sounds. Audible speech has, in this way, been transmitted to a distance of three hundred miles, perfectly intelligible to those who have become accustomed to the peculiarities of certain of the sounds. All parts of a tune are transmitted with great distinctness and with magical effect.

This telephone was exhibited in operation at the Centennial Exhibition, and was considered by the judges the greatest marvel hitherto achieved by the telegraph. The invention is yet in its infancy, and is susceptible of great improvements."

Int. 180. I find that I have omitted to ask you who assisted in the preparation of the draft of your provisional specification for your British patent No. 4765, dated December 9, 1876. Please now state.

Ans. Mr. George W. Gregory, patent solicitor, No. 34 School Street, Boston.

Int. 181. It appears in evidence that on January 13, 1877, you signed and made oath to your application which resulted in the issue of patent No. 186,787, of January 30, 1877, here in suit, and that such application was filed in the Patent Office of the United States, January 15, 1877. The oath appears to have been taken before Henry R. Elliott, United States Commissioner for the District of Columbia. Did you remain in Washington from the date of your arrival, just before beginning to testify in the *Harmonic Telegraph Interferences*, January 2, 1877, until after the date when you so executed your application — January 13, 1877?

Ans. I did.

Int. 182. Where was your application for patent No. 186,787, of January 30, 1877, prepared, and by whose assistance?

Ans. It was prepared in Washington, with the assistance of my patent solicitors, Messrs. Pollok & Bailey.

Int. 183. Did you, during your stay in Washington just referred to, make any public exhibition of your electric speaking telephones, and if so, when, and under what circumstances?

Ans. Yes. I exhibited my speaking telephones, in operation, to the members of the Philosophical Society of Washington, on the evening of January 13, 1877.

Int. 184. Have you recently consulted the published records of the Philosophical Society of Washington, and if so, will you state who were its principal officers at that time; who among them were present, according to your recollection; what record you find relating to the meeting of January 13, 1877, and to what extent such record accords with your memory of the events?

Ans. I have, within a day or two, at the library of the American Academy of Arts and Sciences, in Boston, consulted Vol. II. of the published *Bulletin of the Philosophical Society of Washington*, containing the proceedings from October 10, 1874, to November 2, 1878.

I find from these records that at the Sixth Annual Meeting, held November 4, 1876, the following officers of the society were elected for the then ensuing year :

President, Joseph Henry.

Vice-Presidents, J. K. Barnes, J. E. Hilgard, W. B. Taylor, J. C. Welling.

Treasurer, Cleveland Abbe.

Secretaries, J. H. C. Coffin, T. N. Gill.

Members of the General Committee, S. F. Baird, E. B. Elliott, Asaph Hall, N. S. Lincoln, S. Newcomb, O. M. Poe, C. A. Schott, J. M. Toner, J. J. Woodward.

I find on pages 102 and 103 the following record of the 116th meeting, held January 13, 1877 :

JANUARY 13, 1877.

116th Meeting.

The President in the chair.

Forty-nine members and visitors present.

Mr. *Alexander G. Bell*, of Boston, made a communication on

THE TELEPHONE,

which he had invented, exhibiting and describing its construction and explaining the principles on which it is operated.

The sound of the human voice received on a small plate of thin Russian sheet-iron was conveyed by a telegraphic wire to a similar apparatus in another room and repeated by the vibrations of a similar iron plate.

He stated that he made use of an undulatory, instead of an intermittent current, that no battery was necessary, but that the variations of intensity were produced by the vibrations of the soft-iron plate, varying its distance from the poles of an electro-magnetic helix just behind it. He stated that the experiment had been successfully conducted where the operator and hearer were 153 miles apart.

He referred also to an experiment made by *Professor Henry*, many years ago, where an air played on one piano was repeated by another on the opposite side of the street, a rod of soft pine in contact with the sounding-boards of each forming the connection.

Mr. *Hilgard* and Mr. *Henry* spoke of the value and astonishing character of Mr. Bell's discovery and invention.

Mr. *Bell* having spoken of the difficulty with such consonants as p, t and k, Mr. *Mason* suggested that such an instrument, when perfected, might be used in analyzing linguistic sounds.

I remember that Professor Henry personally presided at the meeting, and that Professor Hilgard also was there, but my memory does not warrant me in stating the names of the others who were

present from memory alone. The record states that there were forty-nine members and visitors present, and my remembrance is that the room was pretty well filled on the occasion. The record accords very well with my memory of the events.

Int. 185. Was any other public record of that meeting made; if so, where, and when was it published?

Ans. Yes. An account of the meeting was published in the *Evening Star*, in Washington, D. C., on Saturday, January 20, 1877. I cut out the notice at the time, and preserved it in my scrap-book, and it is now before me.

[*Counsel for defendants puts in evidence a copy of the newspaper article thus referred to by the witness, and it is marked "Defendants' Washington Star article of January 20, 1877, H. L. H., Special Examiner."*] *

Int. 186. Was the description of your electric speaking telephones contained in this article in the *Evening Star* of Saturday, January 20, 1877, published in Washington, D. C., a correct description, as far as it went, of the electric speaking telephones which you exhibited before the Philosophical Society of Washington, on the evening of January 13, 1877?

Ans. So far as my recollection serves, the description was substantially correct. The speaking-tube, however, was not of gutta-percha, but of India rubber, with a mouth-piece of hard rubber or wood, or some other hard substance. I notice, also, that the reporter, speaking of the iron pole-pieces attached to the permanent steel horse-shoe magnet, says:

"These armatures were wrapped with a fine insulated wire, connected at one end with the earth," etc.

This was the arrangement when the instruments were used on a real line, but such a connection was not made at the meeting of the Philosophical Society, unless, indeed, connection was made at either end with the gas pipes or water pipes. I think, however, a return wire was used to represent the earth. I am inclined to think also

*The *Washington Star* article describes at length, in non-technical language, the exhibition by Mr. Bell of his invention before the Washington Philosophical Society.

that the reporter may have been mistaken in the length of the iron pole-pieces or armatures, which he stated were three inches long. My recollection indicates that they were considerably shorter than that. The account, as a whole, however, I think is substantially correct.

Int. 187. I think that these two accounts contained in the bulletin of the Philosophical Society of Washington, and in the *Evening Star* of Washington, respectively, indicate that each of your telephone instruments exhibited on the evening of January 13, 1877, to the Philosophical Society of Washington, had the cores of its electro-magnet permanently magnetized by contact with a permanent steel horse-shoe magnet, and had a diaphragm of thin sheet-iron, and further, that no battery was used upon the circuit; but in order that the matter may be made certain, I will ask you to state categorically what the fact was.

Ans. Such was the fact. Each telephone instrument had the cores of its electro-magnet permanently magnetized by contact with a permanent steel horse-shoe magnet, and had a diaphragm of thin sheet-iron, and the two similar instruments so constructed were placed in different rooms and were connected together without any battery upon the circuit. At the conclusion of the meeting, the members of the Philosophical Society were invited to test the operation of the instruments, and most if not all of those present availed themselves of the opportunity. Conversation by word of mouth was successfully carried on through these instruments.

Int. 188. In the published bulletin of the 116th meeting of the Philosophical Society of Washington, after brief references to the telephone instruments which you exhibited on January 13, 1877, appears the following — referring to your remarks:

“He stated that the experiment had been successfully conducted where the operator and hearer were 153 miles apart.”

In the account of the same exhibition, published January 20, 1877, in the *Evening Star*, of Washington, occurs the following language — after the description of your telephone instruments:

“In this case the wire through which the communications were transmitted was only a few hundred feet in length. But the experiment has been successfully made where the two operators, or the

operator and the hearer, were in different cities, 153 miles apart. Mr. Bell converses habitually in Boston with a friend in Cambridge through eight miles of telegraph wire. A greater distance than 153 miles has not been tried," etc.

To what experiment did you thus refer on that occasion?

Ans. I referred to the experiment between Boston, Mass., and North Conway, N. H., made on Sunday, December 3, 1876, and alluded to in my answer to Interrogatory 175.

Int. 189. In the experiments so made on Sunday, December 3, 1876, on a telegraph line between Boston, Mass., and North Conway, N. H., what was the character of the apparatus then tried, and what were the results obtained therewith?

Ans. I cannot tell the character of all the apparatus used, for a great many experiments were made, occupying quite a long period of time, with quite a variety of apparatus. I remember that when Mr. Watson started for North Conway he took a great deal of apparatus with him, all or most of which we tested during the experiments on December 3, 1876. Before that time we had been testing in the laboratory at Exeter Place telephones containing electro-magnets operated by means of battery currents, and telephones containing electro-magnets operated by permanent magnets without any battery upon the line, and about the first of December we had come to the conclusion that the permanent-magnet telephone possessed many advantages over the other for operation upon long lines, and my recollection is that the matter was put to a decisive test in the experiments made between Boston and North Conway on the 3d of December, 1876, and that the results demonstrated that the deductions made from laboratory experiments on the Cambridge line, and on circuits containing high artificial resistances, were correct, and that from this time onward we gave up the use of the battery altogether in our further developments in the laboratory. While I cannot recall the character of all the apparatus employed on that occasion, I have the recollection that during the course of the experiments made on the 3d of December, 1876, telephones were used at either end of the line, each of which had a metallic diaphragm of iron or steel in close proximity to the pole or poles of the electro-magnet, the core or cores of which were either themselves

permanently magnetic, or were rendered permanently magnetic by contact with the pole or poles of a permanent magnet, and that these telephones were successfully operated between Boston and North Conway, without any battery upon the circuit, for the transmission of articulate speech. That has been my general recollection, and now that my memory has been refreshed by the account of the remarks I made to the Philosophical Society of Washington, on the 13th of January, 1877, as published in the *Bulletin* of the society, and in the Washington *Evening Star*, I feel perfectly confident of the fact.

Int. 190. When was the next public exhibition of your electric speaking telephones, where did it take place, and what published account of the same appeared?

Ans. An exhibition of the telephone was made at the office of the Boston Rubber Shoe Company on Congress Street, Boston, at noon, on Wednesday, January 31, 1877, on a line running to Malden — about six miles distant. An account of this exhibition was published in the *Boston Evening Transcript* on Thursday, February 1, 1877. I cut out the article at the time, and preserved it in my scrap-book, together with a short editorial notice relating to it, published in the same issue of the *Transcript*, and have the articles before me now.

[*Counsel for defendants puts in evidence copies of the editorial notice and descriptive article just referred to by the witness, and the same are marked "Defendants' Exhibit Boston Transcript Articles of February 1, 1877, H. L. H. Special Examiner."*]*

Int. 191. The editorial notice just referred to states that the account of the experiments performed by you on the preceding day (January 31, 1877) was from the pen of an English gentleman well known as a writer for the press, and the initials "C. H. H." appear at the end of the descriptive article. Do you happen to know who the writer was?

Ans. No. I do not know who he was.

* The *Transcript* article gives a good description of the instruments and of their use between Boston and Malden. The editorial notice referred to speaks of the article as "one of the most intelligible descriptions of the instrument and its mode of operation that we have seen in print."

Int. 192. Was the description of your electric speaking telephones contained in that *Boston Transcript* article of February 1, 1877, a correct description of the electric speaking telephones which you used in the exhibition upon the line from the office of the Boston Rubber Shoe Company, on Congress Street, Boston, to the residence of Mr. Converse, at Malden, on January 31, 1877? And were the results of the experiments on that occasion as stated in the same article?

Ans. Yes. The description of the electric speaking telephones used upon that occasion and of the results obtained was substantially correct. The telephone consisted of a powerful compound horse-shoe permanent magnet, with pole-pieces of iron which were surrounded by coils of insulated copper wire. The ends of the pole-pieces were in close proximity to the surface of a diaphragm of iron. A mouth-piece was used which was placed to the mouth when the telephone was used as a transmitter, and to the ear when it was used as a receiver. This was the construction of the telephone used at the Boston end of the line where I was stationed. My recollection is that the telephone at the Malden end of the line was of similar construction. The two instruments were operated without any battery upon the circuit. My recollection of the results obtained upon this occasion tallies with the account given in the *Transcript* article under consideration.

Int. 193. Was there not a public exhibition of your electric speaking telephones, between that before the Philosophical Society of Washington, January 13, 1877, and that on the line from Boston to Malden, January 31, 1877; and if you recall it to mind, state when and where it took place, and what public notices of it appeared.

Ans. I find by reference to my newspaper scrap-book that there was such a public exhibition, on Sunday, January 21, 1877, on the lines of the Eastern Railroad, between Boston and Salem, and I now remember the circumstance. The exhibition was noticed on Monday morning, January 22, 1877, in the *Boston Post*, *Boston Daily Globe*, and *Boston Daily Advertiser*. I cut out these newspaper notices at the time, and pasted them in my scrap-book, and they are now before me. The following is the account that was published in the *Boston Daily Advertiser* of Monday morning, January 22, 1877:

"TELEPHONY."

The most important of the tests made recently by Professor A. Graham Bell in the practical development of telephony is dispensing with the use of the battery entirely, so that now all that is required to communicate between the most distant places is simply a line of wire and the telephones.

Yesterday morning successful experiments were made between Boston and Salem on the Eastern Railroad wire. At the Boston end were Professor Bell, Mr. Nutting, the operator, Mr. E. H. Foster, Mr. William Auld and Mr. J. B. Parker: and at the Salem end Mr. S. A. Watson, who is associated with Mr. Bell, and the lady operator. •

Recently two Japanese gentlemen conversed in their own language through the telephones, and had no difficulty in understanding all that they said. An experiment has been made in overcoming an artificial resistance greater than the Atlantic cable, and there is no doubt but that it will be possible to talk across the Atlantic."

While the notices of the *Boston Post* and *Boston Daily Advertiser* were headed "Telephony," the account in the *Boston Daily Globe* was headed "Talking by Telegraph."

The electric-speaking telephones used upon that occasion had metallic diaphragms of iron or steel, and electro-magnets, the cores of which were permanently magnetized by contact with the poles of horse-shoe permanent magnets. My impression is that the instruments were the same that had been used in the exhibition given to the Philosophical Society of Washington, January 13, 1877. Conversation was carried on between Boston and Salem by means of these instruments, no battery being used upon the circuit.

Int. 194. Did you give public exhibitions of your electric speaking telephones in February, 1877, and, if so, upon what dates, and in what place or places?

Ans. Yes. I gave a public lecture upon telephony before the Essex Institute, in Lyceum Hall, Salem, on Monday, February 12, 1877. My laboratory in Boston was connected with the Lyceum Hall by means of one of the wires of the Atlantic and Pacific Telegraph Company, and permanent-magnet telephones with metallic diaphragms contained in closed wooden boxes were used at either end. Mr. Watson operated the telephone in Boston, and succeeded in making his articulation audible to a large audience in Lyceum Hall in Salem. No battery was used upon the circuit.

Two days after the lecture, an invitation was extended to me, signed by some of the principal citizens of Salem, requesting a repetition of the lecture. In consequence of this invitation, I repeated the lecture in Lyceum Hall, on Friday, February 23, 1877, before a large audience. Connection was made with Boston, as before. Words uttered by Mr. Watson in Boston were heard in Salem by an audience, I should think, of about five hundred people.

On both these occasions — February 12 and February 23 — accounts of the meetings were transmitted *viva voce* by telephone to Boston to a representative of the *Boston Daily Globe*, and were published in that newspaper on the following mornings, respectively, namely, Tuesday morning, February 13, 1877, and Saturday morning, February 24, 1877. I cut out the published accounts, together with an editorial notice in the *Boston Daily Globe* of February 13, 1877, at the time, and preserved them in my scrap-book. They are now before me.

[*Counsel for defendants puts in evidence the newspaper articles referred to by the witness, and they are marked respectively "Defendants' Exhibit Boston Globe Articles of February 13, 1877, H. L. H., Special Examiner," and "Defendants' Exhibit Boston Globe Article of February 24, 1877, H. L. H., Special Examiner."*]*

Int. 195. What other newspaper notices of these Salem lectures did you cut out and preserve at the time, and paste into the scrap-book which is now before you?

Ans. I have before me notices of the Salem exhibition of February 12, 1877, which were published in the following papers:

Boston Daily Advertiser, February 13, 1877.

The Republican, of Springfield, Mass., February 14, 1877.

The Providence Press, February 14, 1877.

The Republican, Springfield, Mass., February 15, 1877.

Salem Register, February 15, 1877.

The Salem Observer, February 17, 1877.

*The notice from the *Globe* describes at length Mr. Bell's lecture at Salem, but is now remarkable only in the fact that it claims to be "The First Dispatch Ever Sent to a Newspaper by the Newly-invented Telephone, Professor A. Graham Bell's System of Transmitting Sound by Telegraph." Toward the end of the description the writer speaks of "a feat never before attempted — that is, the sending of a newspaper dispatch over a space of eighteen miles by the human voice."

Sunday Times, of Portland, Me., February 18, 1877.

The Sun, of New York, February 20, 1877.

I also have before me notices of the Salem exhibition of February 23, 1877, which were published in the following newspapers :

Boston Herald, February 24, 1877.

Boston Post, February 24, 1877.

Boston Daily Advertiser, February 24, 1877.

Evening Transcript, of Boston, February 24, 1877.

The Providence Press, February 24, 1877.

Further notices of the Salem exhibition of February 12 appeared in :

Boston University Beacon, February 28, 1877.

Journal of Chemistry, of Boston, March 1, 1877.

Central Canadian, of Carleton Place, Ontario, March 1, 1877.

The Athenæum, of London, England, March 3, 1877, referred to the *Boston Daily Globe*, U. S., of February 13, 1877, and to the Salem exhibition noticed therein.

A notice of my Salem lectures also appeared in the *Daily Graphic*, of New York, Tuesday March 6, 1877, accompanied by three pictorial illustrations; the first entitled "Professor Bell's Lecture and Demonstration in Lyceum Hall, Salem, Mass."; the second, "Blackboard Exhibited at the Salem Lecture"; the third, "A Scene at Professor Bell's Experimenting Room, No. 5 Exeter Street, Boston." Notice of the Salem lecture also appeared in the *Daily News*, of London, England, March 9, 1877. An account, accompanied by pictorial illustrations, was published also in the *Scientific American*, of New York, March 31, 1877, in an article entitled "The Telephone." *Frank Leslie's Illustrated Newspaper* of March 31, 1877, likewise contained an account of the same lecture, with pictorial illustrations.

[*Counsel for defendants puts in evidence a copy of the article published in the Scientific American, March 31, 1877, entitled "The Telephone," to which the witness has alluded, and it is marked "Defendants' Exhibit Scientific American Article of March 31, 1877, H. L. H., Special Examiner."*] *

* The *Scientific American* article is a somewhat technical description of Mr. Bell's telephone, and states that the human voice has recently been carried by it over 143 miles,—meaning from Boston to North Conway, N. H. The article states that at the first favorable opportunity a practical test of the powers of the instrument over one of the trans-Atlantic cables will be attempted. The article further speaks of the abolition of the battery and electro-magnets and the substitution of the permanent magnet as the most important improvement yet made.

Int. 196. Did you during the spring of 1877 try your electric speaking telephones upon a telegraph line from Boston to New York, and if so, what was the date, and, how did the experiments result?

Ans. I did; on April 3, 1877. My laboratory in Exeter Place was connected with one of the lines of the Atlantic and Pacific Telegraph Company, leading to New York, and while in New York, I conversed with Mr. Watson, who was at the time in my laboratory at Boston. I fix this date by reference to a notice of the experiment which was published in the *Boston Daily Globe*, on Thursday, April 5, 1877. I preserved this notice in my scrap-book, at the time, and it is now before me. I quote from it the following:

"NEW YORK, April 4. — Professor A. Graham Bell made an experiment with his telephone, over the Atlantic and Pacific Telegraph Company's wires, between Boston and New York, last night; the professor, who was in this city, communicating with his assistants in Boston. The experiment was a great success. Everything said by the professor's assistants was plainly heard by those in attendance here, the conversation being carried on at the ordinary rate of talking."

Notice of the same event appeared in the *Boston Daily Advertiser* on April 5, 1877.

Int. 197. Did you give other exhibitions of your electric speaking telephones, and lectures upon the same; and, if so, will you briefly mention the next notable one following the Salem exhibitions and lectures?

Ans. I did. The next notable exhibition and lecture were given in Providence, R. I., Thursday, April 5, 1877. The lecture was given in Music Hall, Providence, to a very large audience; I should think there must have been a couple of thousand people there.

A telegraph pole was erected near the platform, and telephones were arranged in different parts of the hall, with a switch upon the platform by means of which I could connect the telegraph line leading to Boston with any of the telephones in the hall. The telegraph line was connected at the Boston end with my laboratory, at No. 5 Exeter Place. Mr. Watson had charge of the arrangements at that end of the circuit. My lecture was illustrated by the transmission

of articulate speech from Boston to Providence, and by loud musical effects that could be heard all over the hall.

Notices of this appeared April 6, 1877, in the *Boston Daily Globe*, *Boston Daily Advertiser*, *Boston Post*, and in the *Daily Journal* of Providence.

Int. 198. Did you give public exhibitions of your electric speaking telephones, and lectures thereon, in Boston; if so, when and under what circumstances?

Ans. I did, in response to the following invitation, the original of which I have here before me :

BOSTON, April 20th, 1877.

PROFESSOR ALEXANDER GRAHAM BELL.

Sir :

The undersigned, having followed with great interest the accounts of your discoveries and inventions in connection with the electric telephone, which have from time to time appeared in the newspapers, and confident that the general public of the city in which your researches have been made will be glad to witness a practical exhibition of your telephone under your direction, respectfully request you to gratify this desire of your fellow-citizens, at such time and place as may be most convenient to you.

BENJAMIN PEIRCE,
JOSEPH LOVERING,
E. N. HORSFORD,
HENRY W. LONGFELLOW,
GEO. B. EMERSON,
O. W. HOLMES,
CHARLES W. ELIOT,
ALEXANDER H. RICE,
NEHEMIAH GIBSON,
FREDERICK O. PRINCE,
WILLIAM F. WARREN,
JOHN D. RUNKLE,
C. F. ADAMS,
WOLCOTT GIBBS,
EDWARD C. PICKERING.

In response to this invitation I gave three lectures, in Music Hall, Boston, on Friday, May 4, 1877, Monday, May 7, 1877, and Tuesday, May 8, 1877, respectively. These lectures were noticed at considerable length in the Boston newspapers of May 5, May 6, May 8 and May 9, 1877.

Int. 199. Did you give exhibitions of your electric speaking telephones, and lectures upon the same, in the city of New York; if so, when and under what circumstances?

Ans. Yes. I gave three lectures, at Chickering Hall, in New York, in response to an invitation dated April 7, 1877, and signed by the following gentlemen:

F. A. P. BARNARD (President of Columbia College).

HOWARD CROSBY (Chancellor of New York University).

HENRY MORTON (Stevens Scientific School).

E. L. YOUMANS (Editor, Popular Science Monthly).

CYRUS W. FIELD (Atlantic Cable).

THOS. T. ECKERT (President, Atlantic & Pacific Tel. Co.).

A. M. MAYER (Stevens Scientific School).

WILLIAM ORTON (President, Western Union Telegraph Co.).

J. S. NEWBERRY (School of Mines, Columbia College).

C. F. CHANDLER (Professor Chemistry, College Physicians and Surgeons).

H. D. NOYES (Professor Aural Surgery, Bellevue College).

JNO. W. DRAPER (Professor Chemistry, New York University).

My first lecture in Chickering Hall was given on Thursday, May 17, 1877; the second lecture on Friday, May 18, 1877; and the last lecture Saturday, May 19, 1877. These lectures received extended notices in the New York daily newspapers of May 18, May 19 and May 20, 1877.

Int. 200. You have spoken of producing speech and music through your telephones at these public exhibitions so loud as to be heard by the audience. To what extent were the electric speaking telephones, so exhibited, capable of transmitting and reproducing articulate speech so loudly as to be recognized and understood at considerable distances from the receiving instruments?

Ans. As a general rule, with the most powerful instruments, it was necessary to put the ear close up to the telephone to understand what was said; but tests of that sort were unsatisfactory to a public audience, as all the members wished to hear something. I was, therefore, accustomed to ask Mr. Watson to shout into his telephone as loudly as he could. Under these circumstances, persons at a con-

siderable distance away from the receiving instrument could hear his voice, and persons who were quite near would sometimes understand what was said — especially when familiar sentences were employed and the words were known beforehand.

Int. 201. It has appeared from your testimony that at the time of the Salem and Providence exhibitions, Mr. Watson operated the transmitting instruments in Boston. During the exhibitions and lectures at Music Hall in Boston, May 4, 7 and 8, and at Chickering Hall, in New York, May 17, 18 and 19, were the transmitting instruments at considerable distances from the halls where you lectured?

Ans. Yes. They were many miles away.

Int. 202. When did you first make an electric speaking telephone instrument having its permanent magnet located within a cylindrical case small enough to be grasped by the hand; or, in other words, when did you first make what has now come to be known as a hand telephone?

Ans. In May, 1877.

Int. 203. Did you publicly exhibit such a hand telephone during May, 1877, and if so, on what occasion, and what record have you of it?

Ans. I did. I exhibited such a telephone at the 210th Meeting of the Society of Arts, in Boston, on May 24, 1877. About 250 people were present. The meeting was held in the building of the Massachusetts Institute of Technology. I made an address upon the subject of telephony, and among other apparatus I exhibited a portable telephone having the permanent magnet and coil in the handle. This was connected with another telephone in a distant part of the Institute Building. As I remember the experiment, I had someone singing or talking all the time to the transmitting telephone, and the portable receiver was handed around among the audience so that each one might hear. A report of the meeting, by the Secretary of the Society of Arts, was published in the *Evening Transcript*, of Boston, on Monday, June 11, 1877. I cut it out of the paper at the time, and preserved it in my scrap-book, and it is now before me. The portion referring to the hand telephone is as follows: —

"He exhibited a new and portable telephone, having the magnet and coil in the handle; this was passed round among the audience, who were thus enabled to hear music and conversation in a far distant room in the building. He had made a serviceable instrument which he could carry in his vest pocket."

Int. 204. Please describe the construction of the first hand telephone which you made, as mentioned in Interrogatory 202 and your answer thereto.

Ans. This instrument contained a U-shaped permanent magnet. I should say about six inches in length. The two parallel legs were pretty close together so as to allow of the magnet being placed inside a cylindrical wooden case of small enough diameter to be easily grasped by the hand, and thus form a handle by which the telephone could be lifted to the mouth or ear as required. I should think the diameter of the handle thus formed would be about an inch and a half. It was somewhat stouter than the commercial hand telephone now in use. The upper ends of the legs of the U-shaped magnet were bent outwards away from one another at right angles to the main legs, and were provided with pole-pieces of iron extending in a direction parallel to the main portion of the legs. I think the pole-pieces were about a quarter of an inch long, and perhaps a quarter of an inch in diameter. Each iron core was surrounded by a flat coil of fine insulated copper wire less than a quarter of an inch long, by three quarters or one inch in diameter. In front of the coils and almost touching the outer ends of the pole-pieces was a thin metallic plate of either iron or steel about three or four inches in diameter. This plate formed the lid of a closed wooden box or case containing the magnet and coil. The metallic diaphragm also was provided with a wooden cover having a shallow recess next the plate, and a hole in the centre of the cover fitted with a slightly flaring mouth-piece of wood, somewhat like the mouth-piece shown in Fig. 1 of my patent of January 30, 1877, No. 186,787, only in this case the tube E was omitted, and the mouth-piece fitted directly to the wooden cover. The wooden cover and mouth-piece were circular in shape and were attached to the rest of the case — I think by screws. The shape of this hand telephone, taken as a whole, was very similar to that of the present commercial hand telephone, excepting that the

diameter of the case containing the diaphragm was considerably larger, and the mouth-piece projected beyond the cover of the case and was made as a separate piece.

Int. 205. At the time when you gave directions to have this first hand telephone which you have described made, was it the only one which you gave orders to have constructed?

Ans. No. I gave orders for the construction of four hand telephones, all to be of the same general shape, but two to contain U-shaped permanent magnets, and two to contain straight-bar permanent magnets.

Int. 206. In the printed publication of your lecture at London, England, before the Society of Telegraph Engineers, October 31, 1877, appeared the following statement:

"The convenient form of mouth-piece shown in Fig. 29, now adopted by me, was invented solely by my friend Professor Peirce." And reference was also made to the experiments of Professor Peirce and other gentlemen in Providence, R. I. When, with reference to the date of the construction of your first hand telephone which you have described, did you first have any knowledge or information of the construction of a hand telephone by anyone else than yourself, and what particular feature as distinguished from the mouth-piece of your own hand telephone did you intend to give Professor Peirce credit for devising?

Ans. Two or three days after the completion of the hand telephone with U-shaped permanent magnet and projecting mouth-piece which I have just described, I received from the Providence gentleman referred to a pair of hand telephones containing a combined cover and mouth-piece in one piece, similar to that shown in Fig. 29 of my London lecture referred to, and substantially similar also to the combined cover and mouth-piece in the ordinary commercial hand telephones now used. I intended to give Professor Peirce credit for the difference between the combined cover and mouth-piece shown in Fig. 29 of my London lecture, and the cover and projecting mouth-piece devised by myself and described in my answer to Interrogatory 204.

I had no knowledge or information of the construction of a hand telephone by anyone else than myself, until I had actually con-

structed the hand telephone described in my answer to Interrogatory 204. I am inclined to think that I had completed two, if not three, hand telephones before I heard of anyone else having the idea of a hand telephone. However this may be, I know that one, at all events, had been completed and tested.

Int. 207. State briefly the circumstances under which you prepared and delivered the lecture before the Society of Telegraph Engineers in London, England, on October 31, 1877, and under which an account of the same was printed.

Ans. I was invited to give a popular lecture upon the telephone before the Society of Telegraph Engineers in London. I made an address upon the subject, giving my general recollection of the sequence of inventions that led up to the telephone. The only memoranda I had to assist my recollection were my paper of May 10, 1876, read before the American Academy of Arts and Sciences, copies of my patents, and various newspaper notices. The stenographer's notes of this address were brought to me for correction and revision, and were ultimately published by the Society of Telegraph Engineers.

Int. 208. Was a copy of the lecture so delivered by you in London, England, October 31, 1877, and printed by the Society of Telegraph Engineers, put in evidence in any of the telephone suits which were brought to hearing before the Supreme Court of the United States?

Ans. Yes. The whole lecture was put in evidence in the case of *American Bell Telephone Company v. People's Telephone Company*.

Int. 209. In that London lecture, after an account of your trial of the first magneto-electric telephone instruments with membrane diaphragms, there occurred the following statement: "The results, however, were unsatisfactory and discouraging." Was that sentence a strictly appropriate expression, in view of the actual occurrences and of your own state of mind at the time of the experiments referred to?

Ans. I think perhaps the idea I intended to convey would have been better expressed if I had said that the results were disappointing. But I did not intend to convey the idea that I was in any way myself discouraged by the results, disappointing though they were. My actual condition of mind at the time is shown by a nearly con-

temporaneous letter which I wrote to Mr. Hubbard on August 14, 1875, and which has been put in evidence in this case.

Int. 210. In the same London lecture occurred the statement in reference to the Centennial Iron-Box Receiver, that "its great defect consisted in the fact that it could not be used as a transmitting instrument." Did that language properly characterize the capacity of a magneto telephone constructed upon the plan of such iron-box receiver?

Ans. The language quoted referred to the actual instrument shown at the Centennial, and not to the type of instrument. The Centennial Iron-Box Receiver had a metallic diaphragm of such stiffness and small diameter that it was not well adapted to be set in vibration by the voice, nor were the membrane telephones well adapted to act as receivers when the Centennial iron-box instrument was used as a transmitter. I had used the instrument as a transmitter, using a membrane telephone as a receiver, and had obtained audible effects, but not nearly so good as when the membrane telephone was used as a transmitter, and the iron-box instrument as a receiver. While, however, that particular instrument did not act well as a transmitter, others constructed upon the same type did. For example, the iron-box instrument which was the duplicate of the one given to Sir William Thomson, and which had a thinner diaphragm of larger diameter than the Centennial iron-box instrument, turned out to be an admirable transmitter.

Int. 211. You have stated that you sailed for Europe on or about August 4, 1877, and remained abroad until November 10, 1878. From what port did you sail August 4, 1877, and where did you land on your arrival in this country, November 10, 1878?

Ans. I sailed from New York on or about August 4, 1877; and I landed at Quebec on or about November 10, 1878.

Int. 212. It appears in evidence that *The Speaking Telephone Interferences*, involving your two patents, No. 174,465, of March 7, 1876, and No. 186,787, of January 30, 1877, were declared March 26, 1878, while you were abroad. It also appears from certified copies which I have here present that you made oath to your preliminary statements in those *Speaking Telephone Interferences* on November 20, 1878. Where were you at the time those preliminary

statements were prepared, and what were the difficulties, if any, in the way of refreshing your memory as to the events therein related?

Ans. I was in the Massachusetts General Hospital in the city of Boston, at the time, under surgical treatment. I understood that the time allowed by the Patent Office, within which my preliminary statement must be filed, would soon expire, and that it was, therefore, necessary for me to prepare a preliminary statement at once. I therefore dictated my preliminary statement in the hospital, during my convalescence, and it represents my recollection of the events narrated, before I had had the opportunity of refreshing my memory by consulting papers and documents that were afterwards collected together. I may add that I arrived in Quebec on the 10th of November, 1878, passed through Toronto on the 12th of November, visited my father's house near Brantford, Ontario, and from there I left almost immediately for Boston. Upon my arrival in Boston, it was found advisable for me to go to the Massachusetts General Hospital. I went there the same day I arrived in Boston and remained in the hospital until after I had executed my preliminary statement.

*[Counsel for defendants puts in evidence a certified copy from the records of the United States Patent Office of the preliminary statements of November 20, 1878, by Alexander Graham Bell, and of the supplemental statement filed May 13, 1879; and the same is marked "Defendants' Exhibit Bell's Preliminary Statements in Speaking Telephone Interferences, H. L. H., Special Examiner."]**

*The interferences which were known in the Patent Office as "*The Speaking Telephone Interferences*" were declared on the 26th of March, 1878, and were lettered from A to M because of the number of issues and parties involved. By order of the Commissioner, March 6, 1879, cases H and F were consolidated, and case K was merged into case I. Later, case No. 1 of a series of 6 interferences declared August 14, 1879, was joined with the lettered series. On September 3, 1880, case M was suspended, and subsequently cases A, B, C, D, E, F, G, I, J, L and No. 1 were proceeded with and presented to the Examiner of Interferences together. In these interferences the parties involved were Mr. Bell (whose two patents had already been granted and were therefore put into interference with the applications of subsequent claimants), J. W. McDonough, T. A. Edison, E. Berliner, G. W. Richmond, Elisha Gray, A. E. Dolbear, A. G. Holcomb, C. E. Chinnock, C. A. Randall, Francis Blake, J. H. Irwin and G. M. Phelps. W. L. Voelker was afterwards made a party to several of the cases.

Briefly stated, the issues involved were the method of transmitting vocal sounds electrically, and the forms of apparatus for which, at the time the interferences

Int. 213. In the *Scientific American* article of March 31, 1877, illustrating your Salem lecture and exhibition of February 12, 1877, mention was made of an experiment with your telephones, in which the human voice was carried over a distance of 143 miles, from Boston to North Conway, N. H. Had there previously to that date — March 31, 1877 — been any other trial of your electric speaking telephones between Boston, Mass., and North Conway, N. H., than that which occurred on Sunday, December 3, 1876, to which you have already alluded?

were declared, the various claimants had asked or obtained patents. Five volumes of evidence were used before the Examiner, including the record which had already been prepared for the *Dowd* case in the Circuit Court. The cases were argued at great length before J. B. Church, then Examiner of Interferences, who filed his opinion July 21, 1883. The opinion makes a book of 348 pages, and is an exhaustive history of the art, and of the progress which each claimant had made in his particular line of invention. Priority of invention was awarded by the Examiner to Mr. Bell in Interferences A, B, C, E, F, I, J and L, being all those to which Mr. Bell was a party, except Interference G, in which, as the issue was defined and explained by the Examiner, J. W. McDonough was awarded priority of invention because of his circuit-breaking receiver. From the decision of the Examiner of Interferences Bell, Edison, and Gray appealed to the Examiners-in-Chief in Interference G, and enough unsuccessful parties to the other Interferences appealed to carry up all the cases heard by the Examiner except cases D, F and I. The appealed cases were argued anew before the Examiners-in-Chief, and a decision was rendered October 23, 1884, of some 50 pages, in which the decision of the Examiner of Interferences was affirmed as to all the issues except G, and as to G, his decision was reversed and priority was awarded to Mr. Bell. Cases A, B, G and No. 1 were then appealed by Voelker, Gray, and McDonough to the Commissioner and were argued for seven days before him. He filed his opinion March 3, 1885, affirming the decision of the Board of Examiners-in-Chief.

Mr. Bell's preliminary statement filed in the *Speaking Telephone Interferences* makes some 15 pages of print and is a condensed history of his work upon the telephone, down to the time of the filing of his application, illustrated by several cuts. It was sworn to November 20, 1878, and annexed to it is a 4-page statement, sworn to on the same date, describing his substitution of an iron disk and a permanent magnet for the stretched membrane and electro-magnet of his first patent. These preliminary statements were returned to Mr. Bell as too voluminous, and he returned them to the Patent Office May 13, 1879, with a tabulated statement giving as briefly as possible for each case the date of conception and reduction to practice of the particular invention.

In 1888, McDonough and Gray made a vigorous effort to re-open and re-try the *Interferences*. After an extended hearing, Commissioner Hall in an exhaustive opinion of nearly one hundred pages, 46 *Official Gazette*, 1245, denied both petitions.

Ans. No. There had been no other trial with electric speaking telephones at Boston, Mass., and North Conway, N.H., with 143 miles of wire between, excepting that of December 3, 1876. Instruments had been tried upon this line the preceding Sunday, November 26, 1876, but the instruments were only 18 miles apart, namely, at Boston and Salem, while the line was grounded in North Conway. The experiments of December 3, 1876, were the only experiments made before the date inquired about—March 31, 1877—in which the transmitting and receiving telephones were themselves separated by more than 100 miles of actual space.

Int. 214. The same *Scientific American* article of March 31, 1877, referred to a prior article in the *Scientific American Supplement* of then recent publication, relating to telephones operated by the battery current. What issue of that periodical was thus referred to, and from what was the article so published derived?

Ans. It related to an article entitled "The Speaking Electric Telegraph," published in the *Scientific American Supplement*, February 10, 1877. I cut out the article at the time it appeared, and preserved it in my scrap-book, and it is now before me. This was derived from an article entitled "Bell's Articulating Telephone," which was published December 22, 1876, in an English journal entitled "Engineering," a copy of which is now before me.

[*Counsel for defendants puts in evidence copies of the two articles last referred to by the witness, and they are marked respectively, "Defendants' Exhibit Engineering Article of December 22, 1876, H. L. H., Special Examiner," and "Defendants' Exhibit Scientific American Supplement Article of February 10, 1877, H. L. H., Special Examiner."*]

Int. 215. You have stated that you became acquainted with the receiving instrument of the Reis telephone on or shortly after November 26, 1874, through Professor Charles R. Cross, of the Massachusetts Institute of Technology, and that Professor Joseph Henry showed you the entire Reis apparatus at the Smithsonian Institution, on March 2, 1875. What did you understand that apparatus to be, and what its mode of operation?

Ans. I understood the apparatus to be a means for producing musical pitch by electricity. I understood that the transmitter con-

stituted a circuit-breaking device, whereby a stretched membrane was enabled to make and break the circuit once at each principal vibration, thus producing upon the circuit an intermittent series of electrical impulses of uniform intensity, corresponding in frequency to the frequency of the vibrations of the membrane. The receiving apparatus I understood to be constituted by the core of an electro-magnet. The sudden magnetization and demagnetization of this core produced a molecular disturbance in the iron core of such a kind as to cause the core to become alternately shorter and longer, accordingly as the current did or did not pass through the coil surrounding it. Thus the frequency of vibration of the iron core of the receiver corresponded to the rate of interruption of the current, and this again corresponded to the rate or frequency of vibration of the membrane of the transmitter. If, then, the membrane of the transmitter was caused to vibrate by the influence of a sound made in its neighborhood, the iron core of the receiver would suddenly expand and contract as many times per second as the membrane vibrated to and fro; the vibrations of the core corresponding in frequency, and in frequency alone, to the vibrations of the membrane, so that the core would produce a sound having the pitch, and the pitch alone, of the sound that had operated the transmitter.

Int. 216. In all that you saw of the Reis apparatus or any part of it, and in all that you learned about the same from Professor Charles R. Cross, or from Professor Joseph Henry, or from anyone else, prior to the issue of your patent No. 174,465, of March 7, 1876, did the thought ever occur to you, or did anybody, to your knowledge or within your information, ever assert or suggest before that date — March 7, 1876 — that the Reis apparatus was capable of transmitting and reproducing articulate speech, or of operating according to the method which you set forth as your invention in that patent No. 174,465?

Ans. No. Such an idea never occurred to me, and no one, to my knowledge or within my information, ever asserted or suggested such an idea, and, indeed, the very mode of operation of the Reis apparatus itself I thought necessarily precluded the idea that it could possibly transmit articulate speech or any quality of sound.

Int. 217. In any printed publication concerning the telephone

invented by Philip Reis, or concerning modifications of his apparatus devised by others, published prior to the date of your patent No. 174,465, did you ever see or know of or bear of any description of the method invented by you of transmitting articulate speech, by causing electrical undulations corresponding or similar in form to the air-vibrations accompanying the articulate speech to be transmitted?

Ans. No; I never did.

Int. 218. Is the method of electrical communication between the transmitting and receiving instruments of the Reis apparatus, as described in any printed publication published prior to the date of your patent No. 174,465, so far as you have any knowledge or belief in respect to such publications or the contents thereof, in any way like your method described in your said patent, and referred to therein as the subject-matter of your invention; or is the method or mode of operation described as performed by the Reis apparatus, in any such printed publications prior to the date of your said patent, capable of transmitting articulate speech?

Ans. To the best of my knowledge and belief, no printed publication, published prior to the date of my patent No. 174,465, attributed to the Reis apparatus a mode of operation like the method described in my said patent, and referred to therein as the subject-matter of my invention. And the method or mode of operation actually described as performed by the Reis apparatus, in any such printed publication prior to the date of my said patent, of which I have any knowledge, I believed and still believe to be incapable of transmitting articulate speech.

Int. 219. When did you first hear the suggestion that the Reis apparatus could be made to transmit articulate speech, and by what method was it suggested or alleged that such a result could be accomplished?

Ans. Not till long after the issue of my two patents, No. 174,465 and No. 186,787. I think that it was not until after the public appearance of variable-resistance transmitters involving the use of carbon, and especially after the appearance of newspaper articles describing Hughes's microphone, that I heard the suggestion made. If I remember rightly, it was suggested or alleged that if the Reis apparatus could be so arranged as not to make and break circuit,

as described in the earlier publications, it might be possible to make it talk by taking advantage of the variable-resistance method used in the microphone and in carbon transmitters, and claimed by me in my patent No. 174,465.

Int. 220. Did you ever attempt to conceal the fact that you knew of the Reis apparatus before you applied for your patent No. 174,465?

Ans. No. On the contrary, in all my public statements concerning the history of the speaking telephone, I gave due credit to Reis. In my paper read before the American Academy of Arts and Sciences, in Boston, on May 10, 1876, I referred to Reis, and gave references to all the publications with which I was acquainted, which in any way referred to his experiments and apparatus. I repeated these allusions and references to Reis in my London lecture, delivered before the Society of Telegraph Engineers on the 31st of October, 1877; and when I was first called upon by the Patent Office to give the history of my speaking telephone, in my preliminary statement of November 20, 1878, in the Speaking Telephone Interferences, I alluded to Reis and his apparatus. Speaking of my conference with Professor Henry, March 2, 1875, I said:

“He showed me the various electrical and acoustical instruments which he had in the Smithsonian Institute, including Reis’s telephone. I had previously seen in the Institute of Technology, in Boston, the receiving instrument of Reis’s telephone, and was acquainted with the construction of the whole apparatus by diagrams and printed descriptions, but I had never before seen the transmitting portion of the apparatus.”

Int. 221. Did you ever have any correspondence with Mr. Elisha Gray, touching the telephonic inventions claimed by him, and the electric speaking telephone invented by you, and if so, when did such correspondence take place, under what circumstances, and what was it?

Ans. Yes. On the 24th of February, 1877, I received a letter from Elisha Gray, from Chicago, dated February 21, 1877, in which he stated that he was going to give a public lecture, and wished to exhibit my method of transmitting vocal sounds by electricity, but did not like to do so without my permission. I have Mr. Gray’s original letter before me. In reply, I sent him a tele-

gram dated February 24, 1877, stating that I would have no objection to his exhibiting my method, if he would publicly refute a statement in the *Chicago Tribune* of February 16, 1877, which I considered to be a libel upon myself. I have here my original draft of that telegram. The statement alluded to referred to Mr. Elisha Gray as "the real inventor of the telephone," and talked of "the spurious claims of Professor Bell." In reply to my telegram, Mr. Gray wrote a letter to me, dated Chicago, February 24, 1877, the original of which is now before me. On the 2d of March, 1877, I replied to this letter, and Mr. Gray, in the *Dowd* case, produced my original letter, a copy of which was put in the record of the *Dowd* suit. Mr. Gray replied to my letter by a letter dated Chicago, March 5, 1877, the original of which is before me.

Int. 222. Will you read, as part of your present answer, the entire correspondence, together with the publication in the *Chicago Tribune* referred to in that correspondence?

Ans. I will. The correspondence and publication are as follows:

(Gray to Bell.)

CHICAGO, Feb. 21, 1877.

PROF. A. G. BELL:

My dear Sir:

I give a lecture in McCormick Hall, this city, Tuesday evening, the 27th inst., on the *telephone*, as I have developed it. I also connect with Milwaukee, and have tunes and telegraphing done from there. I should like to explain and exhibit *your* method of transmitting vocal sounds as well, but do not feel at liberty to do *more* without permission from you. I should explain it as *your* method, and not mine, although the *Office* records show a description of the talking telegraph filed by me the *same* day yours was filed. The description is substantially the same as yours. I was unfortunate in being an hour or two behind you. There is no evidence that either knew that the other was working in this direction.

With our facilities I can get up an apparatus on a day's notice that will answer. I have a copy of your last patent. Please telegraph at my expense, on receipt of this, yes or no, and I will act accordingly.

Yours truly,

ELISHA GRAY,
220 Kinzie St., Chicago.

I send this care Mr. Hayes, as I do not know your address. I

received a line from you through Mr. Baldwin, for which please accept thanks.

(*Bell to Gray, Telegram.*)

BOSTON, February 24, 1877.

ELISHA GRAY,

Western Electric Manufact. Co.

If you refute in your lecture, and in the *Chicago Tribune*, the libel upon me published in that paper February sixteenth, I shall have no objection. Please answer.

A. GRAHAM BELL.

(*From the Chicago Tribune, February 16, 1877.*)

"Many of the Eastern newspapers are favoring their readers with sketches of Professor A. M. Bell, 'the inventor of the telephone.' Meanwhile, the real inventor of the telephone — Mr. Elisha Gray, of Chicago,—minds his own business, and apparently concerns himself not at all about the spurious claims of Professor Bell. Persons acquainted with the subject need not be informed that Mr. Gray's claims are incontrovertible. Science long since recognized them. They were established in the columns of the *Tribune* years ago, before Professor Bell was so much as heard of. They are officially approved in the Patent Office at Washington, and they have already brought in large returns in money as well as in reputation to the inventor. Talking by telegraph and other sport of that description Mr. Gray has not paid much attention to as yet, because there is no present indication in it of anything more than sport; but the principles involved in it were discussed by him and have all been used by him in a practical manner."

(*Gray to Bell.*)

CHICAGO, Feb. 24, 1877.

PROF. A. G. BELL.

Sir:

Your telegram received. In answer, I would say, first, that I do not know what article you refer to, but will see the paper of that date. I have seen one or two articles lately that ventured to assume that you were not the only man in the world who had contributed to the development of the telephone. If such assertions are "*libels*," then you have been *libelled*. So far as I know, the "*libels*" are mostly on the other side, if assertions of *originality*, etc., may be so considered. The papers here have been full of articles of late, copied from Boston papers, claiming the whole development of the telephone for you. It would not be strange if someone, knowing the facts, should speak, and in doing so may have done you injustice.

You seem to assume that I am responsible for all the newspaper articles that are not in your favor. I assert here that I have never

said a word about you in the public prints, and I have always — even to the degree of offending some of my friends — defended you when I have heard disparaging remarks made about you. Since I made your acquaintance I have taken the ground that we were both independent inventors. Now, if we are going into the refutation business I suggest that it be mutual. So far as I know there is quite as much needed from your side as from mine. I am always willing to correct any wrong done you, even if I am not responsible. If we undertake to follow up the newspapers we will have our hands full. I shall not show your apparatus, as I do not want any conditions imposed until I know what I am expected to refute. I do not know but that it is to deny all claim to the invention. Allow me to suggest that your telegram was just a little indiscreet, as it contained an assumption very unjust to me.

I do not know your address, so I send through Mr. Hayes.

Yours truly,

E. GRAY.

P. S. You should have sent your dispatch collect, as I requested it sent.

(*Bell to Gray.*)

BOSTON UNIVERSITY, March 2, 1877.

ELISHA GRAY, Esq., *Chicago.*

My dear Sir:

I was somewhat hasty, I must confess, in sending my telegram, for, of course, you are not responsible for all the ill-natured remarks that may appear in the newspapers concerning me.

I am sorry that my telegram should have prevented you from making the experiments you desired, for it is my sincere desire to oblige you in any way I can. I am glad that you are willing to do me justice, and must thank you for saying a good word for me occasionally. I may say that it has uniformly been my custom to make honorable mention of your name in multiple telegraphy, and to give you the credit of being an independent inventor.

I have not generally alluded to your name in connection with the invention of the electric "telephone," for we seem to attach different significations to the word. I apply the term only to an apparatus for transmitting the voice (which meaning is strictly in accordance with the derivation of the word), whereas you seem to use the term as expressive of any apparatus for the transmission of *musical* tones by the electric current.

I have no knowledge of any apparatus constructed by you for the purpose of transmitting vocal sounds, and I trust that I have not been doing you an injustice. It is my sincere desire to give you all the credit that I feel justly belongs to you.

I do not know the nature of the application for a caveat, to which

you have referred as having been filed two hours after my application for a patent, excepting that it had something to do with the vibration of a wire in water, and therefore conflicted with my patent. My specification had been prepared *months* before it was filed, and a copy had been taken to England by a friend. I delayed the filing of the American patent until I could hear from him. At last the protests of all those interested in my invention, deprecating further delay, had their effects, and I filed my application without waiting for a conclusion of negotiations in England. It was certainly a most striking coincidence that our applications should have been filed on the same day.

I have been kept so busy during the past few days correcting the examination papers of my normal school, that I have been unable to write.

In haste.

Yours truly,

ALEXANDER GRAHAM BELL.

(Gray to Bell.)

CHICAGO, Mar. 5, 1877.

PROF. BELL.

My dear Sir:

I have just received yours of the 2nd instant, and I freely forgive you for any feeling your telegram had aroused. I found the article I suppose you referred to in the personal column of the *Tribune*, and am free to say it does you injustice.

I gave you full credit for the talking feature of the telephone, as you may have seen in the associated press dispatch that was sent to all the papers in the country—in my lecture in McCormick Hall, Feb. 27th. There were four different papers represented at the lecture, but only one—the *Tribune*—alluded to my mention of you, except the “press” dispatch. I described your apparatus at length by diagram.

Of course you have had no means of knowing what I had done in the matter of transmitting vocal sounds. When, however, you see the specification, you will see that the fundamental principles are contained therein. I do not, however, claim even the credit of inventing it, as I do not believe a mere description of an idea that has never been *reduced to practice*—in the *strict sense* of that phrase—should be dignified with the name invention.

Yours very truly,

ELISHA GRAY.

Int. 223. In the deposition of Mr. Elisha Gray, in the case of *Bell Telephone Company v. Peter A. Dowd*, there was given the following extract from an article in the *New York Tribune*, of April

3, 1877, referring to an exhibition given by Mr. Elisha Gray, in New York, on the preceding day :

"After the first part of the programme had been executed, Mr. Elisha Gray came forward and addressed the audience. He was aware that great confusion existed in the popular mind as to what this telephone could perform ; in particular it had been confounded with the speaking telephone invented by Professor A. Graham Bell, of Boston. Professor Bell, Mr. Gray said, was present in the audience."

Were you present in the audience on that occasion, and did the incident related in the extract just quoted take place substantially as therein stated ?

Ans. Yes ; I was present in the audience, and the incident took place substantially as stated.

Int. 224. Did you ever see the original caveat filed by Mr. Elisha Gray in the Patent Office of the United States, February 14, 1876, or any part of the same, or the original drawings or any part thereof belonging to that caveat ?

Ans. No ; I have never seen the original caveat nor any part of it, nor the original drawings, nor any part of them.

Int. 225. When for the first time did you see anything which purported to be copied or derived from the caveat filed by Mr. Elisha Gray in the Patent Office of the United States, February 14, 1876 ?

Ans. In a printed book, by Mr. George B. Prescott, entitled "The Speaking Telephone, Electric Light, and Other Recent Electrical Inventions," published in New York and copyrighted in the year 1878. I understood from the book that the drawing, Fig. 102, on page 216, was copied from Gray's caveat filed February 14, 1876, for the following statement occurs on page 217 : "Mr. Gray's caveat of the same date shows means of producing articulate speech telephonically (Fig. 102)," etc. I have since found, however, that the drawing, instead of being taken from the caveat, was substantially a copy of the drawing, Fig. 4, of an application filed by Mr. Gray in the Patent Office, October 29, 1877.

The book from which I have given the page reference bears the imprint "1879" upon its title page. I do not know exactly when I first saw this book of Prescott's, but I think it was not long after its first publication.

Int. 226. When for the first time did you ever see a copy of Mr. Elisha Gray's caveat of February 14, 1876?

Ans. In the *Dowd* suit, during the cross-examination of Mr. Henry B. Renwick, on January 27, 1879, Mr. Causten Browne put in evidence a certified copy of the caveat referred to. I saw this copy upon that date, or soon afterwards, and that was the first time I ever saw a copy of the caveat.

Int. 227. When, for the first time, did you receive any information that Professor Amos E. Dolbear, of Tufts College, Somerville, Mass., had invented an electric telephone to be operated without a battery, or an electric telephone having electro-magnets with permanently-magnetized cores, or anything whatsoever appertaining to an electric telephone; and by whom was such information communicated to you?

Ans. Mr. Gardiner G. Hubbard spoke of the matter to me, after I returned from Canada, where I spent Christmas, 1876. I went from Canada to Washington, stopping a short time in Boston on the way, and I do not know whether Mr. Hubbard alluded to the matter while I was in Boston, or after I went to Washington.

Int. 228. Did the information which Mr. Gardiner G. Hubbard so communicated to you come directly through him from Professor Amos E. Dolbear, or did you then understand that a third person intervened in transmitting what you then learned?

Ans. No. It did not come to him directly from Professor Dolbear. I understood that Mr. Percival D. Richards had told Mr. Hubbard about Professor Dolbear, and Mr. Hubbard afterwards spoke of the matter to me.

Int. 229. When you thus learned from Mr. Hubbard that Mr. Richards had informed him that Professor Dolbear had invented an electric telephone to be operated without a battery, or an electric telephone having electro-magnets with permanently-magnetized cores, or anything whatsoever appertaining to an electric telephone, did you then understand that Professor Dolbear claimed to have invented those things before you had invented them?

Ans. No. I did not get any such idea as that. I obtained the impression that the remarks referred simply to suggestions or ideas that were in Professor Dolbear's mind.

Ans. I certainly did not say any such thing.

Ans. Yes. I received a letter from Professor Dolbear, dated February 16, which arrived in due course, undoubtedly on the 16th or 17th of February, 1877. I have the original letter with me here present, and it is as follows:

PROF. A. G. BELL:

The other day I visited your room at Exeter Place, and was kindly shown your invention, the Telephone, by Mr. Watson. He mentioned having sent messages through three persons holding hands, but didn't know the resistance of such a circuit. I promised to measure the resistance of the human body in a circuit and send to you, as he thought it would be useful, and gave to me one of your envelopes.

Resistance in Ohms, an Average of 8 Individuals.

From one hand to the other through the body,	hands dry,	10,000+
	hands wet,	6,000
From mouth to hand ,	latter dry, ...	8,000
“ “ “ “ “	wet, ...	5,000

You will notice that I put them all in *round* numbers, but the experiments justify it. There was a wonderful difference in individuals, which surprised me at first. One person having a resistance upwards of 40,000 ohms. I perceived that the reason was the difference in thickness and horniness of the inner skin of the hands. Hence I conclude that you sent your message through a resistance of at least 18,000 ohms, nearly equal to the resistance of 2,000 miles of ordinary telegraph wire. I congratulate you, sir, upon your very great invention, and I hope to see it supplant all forms of existing telegraphs, and that you will be successful in obtaining the wealth and honor which is your due.

Yours truly,

A. E. DOLBEAR.

Int. 232. When and how for the first time did you learn that Professor Amos E. Dolbear was a rival claimant to any part of the inventions which you had made relating to the electric-speaking telephone?

Ans. I learned this for the first time through a letter I received from Professor Dolbear, dated May 6, 1877, and received by me shortly afterward in due course of mail.

Int. 233. If you have that letter here present, please read it as a part of your present answer.

Ans. I have the original letter here present. It is as follows :

COLLEGE HILL, MASS., MAY 6th, 1877.

PROF. A. G. BELL,

My Dear Sir, —

I listened with pleasure to your lecture at Music Hall, last Friday night, but as I understood you to say concerning the latest forms of the Telephone that you were without a competitor, I wish to acquaint you with my connection with this invention, and I hope you will patiently listen to me through a short story.

As long ago as *June, 1864*, while studying electricity at college, and also employed by the prof. of Nat. Science to make some magnets both electro & permanent, I invented substantially this present arrangement and described it to the prof., to the telegraph operator at the place, and endeavored to interest some parties in it, so as to undertake the construction of working instruments. They were all skeptical, and as I had no funds or means beyond those for my college expenses, I had to abandon it. Last fall when reading the remarks of Sir W. Thomson concerning your invention, I at once thought of my former one, & at once began some experiments which resulted in this present form of the Telephone, such as

you use; that is, the inducing permanent magnet & the vibrating plate. This was early in Dec. last. I had not the slightest idea that you were at work on the same line. After I had succeeded in this, I thought of *visiting you and saying to you that what you were doing with a battery* could be as well done without a battery, but my friends persuaded me to keep away from you, to perfect a pair of instruments and obtain a patent for them; this I was doing when your invention of the same thing was made public. I have looked over the patent files and noted that your application dates Jan. 15th, and that the patent was granted on the 30th of that month. To me it appears that I had invented this form while you were yet experimenting with the battery, as for instance between Cambridgeport & Boston, Malden & B. &c.

There are a plenty of persons here who know about these things and can testify that they all preceded any mention of your experiments in the same direction. This, I think, entitles me to at least an equal claim with yourself to this latest form of the Telephone.

I did at one time seriously think of contesting your patent, but I learned that it was always a costly thing & I hadn't a cent to spend for any such purpose, therefore I beg you not to be uneasy in the slightest degree as to your claim.

I shall not interfere. All I would ask of you will be that while giving the work of others upon the subject, you will not entirely ignore me.

It is the commonest thing in the world for two or more persons to hit upon the same idea at the same time, without any knowledge of each other's work, and the history of telegraphy abounds in such incidents, as you know.

This is all I have to say about that matter, and if you will allow me to correct a statement I understood you to make concerning the effect of magnetization upon a piece of iron.

I understood you to say that when a piece of iron was magnetized that it was *shortened*.

It should be *lengthened*. Joule made its increase in length to be about the $\frac{1}{27000}$ of its own length. Mayer, in 1872, made it the $\frac{1}{25000}$ for soft iron. In 1871, I also measured it, using a tilted beam of light 60 ft. long, and also made it $\frac{1}{25000}$ of its length. For *hardened steel* I believe that it is shortened.

Now, my dear sir, I hope that you will not feel any way but kindly towards me, as I admire both your wonderful ingenuity and persistence, and I would love to count you as one of my friends.

I hope that you will yet be able to make the Telephone even to surpass the vision of the wild "Graphic" man, and that you will meet both Fame & Fortune.

Yours truly,

A. E. DOLBEAR.

Int. 234. Professor Amos E. Dolbear has testified in the present suit as follows (answer to Interrogatory 66) :

"Sometime along in the spring of 1877 — I think that it was in May — I met Professor Bell as he was coming out from Music Hall, and had a short talk with him concerning my claim for the magneto-telephone. I think it was a time when he was delivering some lectures in Music Hall, and as I had attended the first one of his lectures at that place, and he had recited some of the history of its development, and as I supposed he knew what I had done or what I claimed to have done in the development of the magneto-telephone, I thought that he did wrong in not mentioning me and my work in reference to it, and I therefore, at the time stated, called his attention to what I took to be an oversight, and he told me at that time and place in the presence of Mr. Gardiner G. Hubbard who was with him, that hereafter when he had occasion to refer to the history of the telephone, he would refer to me."

Did any such meeting with Professor Dolbear take place at the time and under the circumstances so mentioned by him, or did you ever make to him any such promise as he has thus stated?

Ans. I have no recollection of any such meeting, and I feel perfectly sure that I never, at any time, made any promises whatever, of any kind, to Professor Dolbear.

Int. 235. It appears in evidence, from a letter written by Mr. Gardiner G. Hubbard to Professor Amos E. Dolbear, and dated August 5, 1877, that four weeks previously — that is to say, July 8, 1877 — Professor Dolbear had visited Mr. Hubbard's house in Cambridge, and had given an account of his researches in telephony, in the presence of Mr. Hubbard and yourself. Do you remember that occasion, and if so, what part did you take in the conversation?

Ans. I remember the occasion. I was present at the time, but more as a listener than anything else. I allowed Professor Dolbear and Mr. Hubbard to do the talking.

Int. 236. Professor Amos E. Dolbear in his testimony in the present suit, referring to his interview with Mr. Gardiner G. Hubbard and yourself, at Mr. Hubbard's house in Cambridge (which according to Mr. Hubbard's letter of August 5, 1877, took place July 8, 1877), has testified as follows (answer to Interrogatory 66) :

"I made the claim to Mr. Bell that I had invented the permanent magnet telephone which he was using then and had been using for some time, at the time when he was experimenting with the electro-

magnetic telephone, and that, if I had applied for a patent for that at any time prior to the 1st of January, 1877, I should have probably been able to obtain a patent for it, a proposition which I understood him to admit to me as correct. I left the house carrying with me the impression that Mr. Bell was persuaded that I had lawful claims upon the magneto-telephone," etc.

Did you, at the interview thus referred to, make any statement or statements to Professor Dolbear, or in his presence, from which he could legitimately have drawn the conclusion that you admitted the probability of his obtaining a patent for the permanent magnet telephone, if he had applied for it prior to January 1, 1877, or that you were persuaded that he had any lawful claims upon the magneto-telephone?

Ans. I am quite sure from my general recollection of the circumstances, and from my knowledge of my own previous experiments with perfected permanent-magnet telephones, that it was not possible for me to have made any statements that could have justified Professor Dolbear in drawing the inferences or impressions referred to in the quotation you have made from his testimony.

Int. 237. When you made the application which was filed February 14, 1876, and which resulted in the issue of patent No. 174,465, of March 7, 1876, and throughout the prosecution of that application, what was your intention and purpose in respect to conformity with all the requirements of the law relating thereto?

Ans. I intended and desired to conform to all the requirements of the law relating thereto. I believed then and I believe now that I did so.

Int. 238. What was your intention in respect to making in that application all the statements which the law required or contemplated that such application should contain; and what was your belief at the time, and what is your present belief as to whether your said application did, in fact, contain all the statements which the law required or contemplated that such application should contain?

Ans. It was my intention and desire at the time to make in that application all the statements which the law required or contemplated that such application should contain; and I believed then and I still believe that the said application did contain all the statements which the law required or contemplated that it should contain.

Int. 239. What was your belief at the time you made that application, and during its prosecution until the issue thereon of patent No. 174,465, dated March 7, 1876, and what is your present belief in respect to the truth of all the statements made therein by you or on your behalf?

Ans. I believed, and still believe that they were all true.

Int. 240. You have testified that you drew the specification accompanying your application of February 14, 1876, and that you also drew the amendment to that specification filed February 29, 1876. Were the statements contained in that amendment intended by you to describe or suggest as the subject of your application any invention different from or additional to the inventions already described and claimed in the specification of the same patent, filed February 14, 1876?

Ans. No. The amendment of February 29, 1876, was not intended by me to describe or to suggest any invention different from or additional to the inventions already described and claimed in the original specification of the same application, filed February 14, 1876. The amendment was intended simply as a statement which should define the invention in such a manner as to distinguish it more clearly from another invention of my own, described previously by me in an application filed February 25, 1875.

Int. 241. It appears from your testimony that up to the date of the patent No. 174,465, of March 7, 1876, your experiments had not resulted in such transmission of articulate speech electrically as to enable the words thereof to be recognized. When you prepared and made oath to the specification which accompanied your application filed February 14, 1876, and while that application was pending, and when your patent thereon, No. 174,465, was granted, what was the state of your knowledge and belief as to the adequacy and efficiency of the method and apparatus specified and referred to in the 5th claim of your specification belonging to that application and patent, for the purpose of transmitting and reproducing articulate speech?

Ans. I believed that I had, in that application, described an adequate method for the transmission of articulate speech electrically, and had claimed the same in my 5th claim. And I also believed

that the apparatus described in my application and illustrated in Fig. 7 would practically transmit articulate speech intelligibly, if constructed by persons skilled in the art, in accordance with the description given in the specification.

Int. 242. You have, in the last preceding answer, used the expression "persons skilled in the art." What do you mean by that phrase?

Ans. I mean persons skilled in the art of making acoustical apparatus like phonautographs, etc., involving the use of stretched membranes, and also skilled in the art of constructing electro-magnetic apparatus.

Int. 243. It is charged in the bill of complaint in the present suit that you purposely framed your said application and claim in ambiguous and general terms in order to cover both antecedent and future inventions, and to deceive and mislead the Examiners of the Patent Office and the public. When you framed the specification and claims of your application which resulted in the grant of patent No. 174,465, dated March 7, 1876, did you make therein any statement, or use any language whatsoever, which you knew or believed to be ambiguous or to be more general in its signification than was required to define accurately the precise invention which you knew you had originated, and which you believed you were the first to have originated?

Ans. No. On the contrary, I took very great pains and care in the preparation of that specification and claims, with the object of defining as accurately as possible the precise invention which I knew I had originated, and which I believed, and still believe, I was the first to have originated. The preparation of the specification was substantially completed in October, 1875, but from that time up to the very last moment when it was possible for me to amend the phraseology, I was constantly making slight verbal changes with the object of making my meaning more clear and entirely unambiguous; and I thought then, and I still think, that my invention was accurately and precisely described in that application, so that anyone may understand it who reads, and that it does not contain any statement or use any language whatsoever which I knew or believed to be ambiguous or more general in its signification than was required to define accurately the precise invention.

Int. 244. The bill of complaint further charges that in your said application which resulted in the issue of patent No. 174,465, of March 7, 1876, you did not set forth or declare that your invention had any relation to the art of transmitting articulate speech by means of electricity. What have you to say to that charge?

Ans. I can only say that I intended to include in my invention the art of transmitting articulate speech by means of electricity, but I did not intend to limit the invention to the transmission of "articulate speech." I believed and stated that the method and apparatus described in said application and claimed in Claim 5 could be used for "the telegraphic transmission of noises or sounds of any kind," including, of course, articulate speech, and including any and every kind of noise or sound, whether made by the human voice or in any other way. I intended to state, and believe I did state, substantially, that whatever kind of sound should be made in the neighborhood of the cone A, Fig. 7, a similar sound would be heard from the ear-piece L,— I mean a sound of exactly similar character or quality. That I intended to include articulate speech I think will be obvious from the language employed in the specification, where the statements are made that "When a sound is *uttered* in the cone the membrane *a* is set in vibration," etc., and "A similar sound to that *uttered* into A is then heard to proceed from L." In Claim 5 also I specifically stated that I claimed a method of and apparatus for transmitting "*vocal*," as well as other sounds, telegraphically. I believed at the time I drew my specification, and still believe, that if I had described my invention specifically for the purpose of transmitting articulate speech alone, it would have been an inadequate description, not covering fully the scope of the invention. I believed then, and still believe, that by stating the object of the invention shown in Fig. 7 and claimed in the 5th claim to be "the telegraphic transmission of noises or sounds of any kind," I not only defined fully and accurately the complete scope of the invention, but included within its scope the transmission of articulate speech.

Int. 245. The bill of complaint further charges that the title given to your invention in patent No. 174,465, and in your application therefor, wherein it is styled "Improvements in Telegraphy," was misleading and inconsistent if, in fact, you intended such inven-

tion to embrace a method and apparatus capable of transmitting and reproducing articulate speech electrically. Was there, at the time when you filed that application and obtained that patent, any inaccuracy or impropriety in entitling your invention "Improvements in Telegraphy," in view of your intention to describe and claim therein, among other things, a method and apparatus capable of the electrical transmission and reproduction of articulate speech?

Ans. I do not think that at the time I filed that application and obtained that patent there was any inaccuracy or impropriety in entitling my invention "Improvements in Telegraphy." At that time an apparatus capable of the electrical transmission and reproduction of articulate speech was a new thing, and there was no specific name by which to designate it. The word "telephone" had another signification at that date, and was applied to an apparatus of entirely different character. I think it would have been appropriate, at that time, to entitle my invention either "Improvements in Telephony," or "Improvements in Telegraphy." I preferred the latter title, and the word "telephony" had not then, I think, been coined by me. I thought the title "Improvements in Telegraphy" was especially appropriate, as I desired to distinguish the subject-matter of that patent from previous inventions of my own described in other applications before the Patent Office, all of which had reference to telegraphy alone. For a long time after the issue of my patent No. 174,465, not only I, but the whole world, was accustomed to consider an apparatus for the electrical transmission and reproduction of articulate speech as a form of telegraph. In my specification, I spoke of the "telegraphic" transmission of noises or sounds of any kind; and in Claim 5 I claimed a method of and apparatus for transmitting vocal or other sounds "telegraphically." Indeed, it was not until a long time after the issue of my patent of March 7, 1876, that the word "telephony" became a recognized term in the art. For example, my provisional specification, filed in the British Patent Office on the ninth day of December, 1876, was entitled by me "Improvements in Electric Telephony and Telephonic Apparatus"; but the Patent Office would not accept the title without a definition of the new term "telephony," employed. This was accordingly defined by the British Patent Office, or by my solicitors abroad, in

a parenthetical clause, as "Transmitting or Causing Sounds for Telegraphing Messages." Again, as late as 1877, the United States Patent Office classified my application filed January 15, 1877, which resulted in the issue of patent No. 186,787, January 30, 1877, as an "Improvement in Electric Telegraphy," although I had myself entitled the invention in the specification itself as "Improvements in Electric Telephony." For a long time after the granting of my patent of March 7, 1876, the method of and apparatus for transmitting articulate speech electrically was alluded to by people generally in such terms as follows: "telegraphing vocal sounds," "talking by telegraph," etc.; and when the word "telephone" was employed, it was usual to qualify it as "a speaking telephone," "a talking or articulating telephone," etc., so as to distinguish the apparatus from the earlier telephones known, which did not transmit speech. It took a number of years to accustom the world to the use of the word "telephone" alone as a term specifically applied to an apparatus for the electrical transmission of speech.

Int. 246. At the time when you prepared and made oath to the specification which formed part of your application filed in the Patent Office, February 14, 1876, and while that application was pending, and at the date when your patent No. 174,465, was granted thereon, what was the state of your knowledge in respect to your being a true and original inventor of the electric speaking telephone, and of any method capable of the electrical transmission of articulate speech, and what was your belief then, and what is your present belief, as to your being the first inventor of the electric speaking telephone, and of any method capable of the electrical transmission of articulate speech?

Ans. At that time I knew that I was a true and original inventor of an electric speaking telephone, and of a method capable of the electrical transmission of articulate speech; and I believed then, and believe now, that I was the first inventor of any electric speaking telephone, and of any method capable of the electrical transmission of articulate speech.

Int. 247. The bill of complaint in this suit charges that when, on January 20, 1876, you made and verified the application which was filed in the Patent Office February 14, 1876, and which resulted in

the grant of patent No. 174,465, dated March 7, 1876, you did not then, nor at the date of filing said application, verily believe yourself to be the original and first inventor of all the improvements in telegraphy described and claimed in the specification belonging to that application and patent; but did know, and did believe, that certain of the improvements in telegraphy described and claimed in that specification had been previously known to and used by others. Are those charges, or either of them, so made by the bill of complaint, true in any particular or in any manner? In other words, when, on January 20, 1876, you verified your said application, and when, on February 14, 1876, you filed the same in the Patent Office, did you know or believe, or had you any reason to believe, that anyone else claimed to have made, or pretended to have made, the inventions, or either of them, described and claimed in the specification of that application, before the discovery and origination of the same by you, or that anyone asserted or suggested that your said inventions, or either of them, had been invented, known or used by any other person or persons whomsoever, or had been described in any patent or printed publication before you yourself originated those inventions, and each of them, and described them in that application filed February 14, 1876.

Ans. No; I did not know or believe any such thing. The charges referred to as made in the bill of complaint are not true in any particular, or in any manner.

Int. 248. The last preceding interrogatory was a long one, and although I think you have substantially answered every branch of it, I wish you would again consider the latter half of it, and answer it more specifically.

Ans. On January 20, 1876, when I verified my said application, and on February 14, 1876, when it was filed in the Patent Office, I did not know, nor believe, nor had I any reason to believe, that anyone else claimed to have made, or pretended to have made, the inventions, or either of them, described and claimed in the specification of that application, before the discovery and origination of the same by myself, nor that anyone asserted or suggested that my said inventions, or either of them, had been invented, known, or used by any other person or persons whomsoever, or had been described in any patent,

or printed publication before I myself originated these inventions, and each of them, and described them in that application filed February 14, 1876. .

Int. 249. When you filed your application of January 15, 1877, which resulted in the issue of patent No. 186,787, on January 30, 1877, what was your intention as to conformity with all the requirements of the law relating to your said application and patent, and what was your belief, at that time, and what is your present belief, as to whether you did, in fact, conform to all such requirements of the law?

Ans. I intended to conform to all the requirements of the law; and I believed at that time, and now believe, that I did so.

Int. 250. When you filed your application of January 15, 1877, which resulted in the issue of patent No. 186,787, of January 30, 1877, and while that application was pending, and when that patent was granted, did you know or believe, or had you any reason to believe, that anyone else claimed to have made, or pretended to have made, the inventions, or either of them, described and claimed in the specification of that application and patent, before the discovery and origination of the same by you, or did you know or believe, or had you any reason to believe, that anyone had asserted or suggested that your said inventions, or either of them, had been invented, known, or used by any other person or persons whomsoever, or had been described in any patent or printed publication before you yourself originated those inventions and each of them?

Ans. No. When I filed my application of January 15, 1877, which resulted in the issue of patent No. 186,787, of January 30, 1877, and while that application was pending, and when that patent was granted, I did not know, nor believe, nor had I any reason to believe, that anyone else claimed to have made, or pretended to have made, the inventions, or either of them, described and claimed in the specification of that application and patent before the discovery and origination of the same by myself. And I did not know nor believe, nor had I any reason to believe, that anyone had asserted or suggested that my said inventions, or either of them, had been invented, known, or used by any other person or persons whomsoever, or had been described in any patent or printed publication before I myself originated these inventions and each of them.

Int. 251. You have mentioned three visits to Washington before you went abroad, August 4, 1877 — the first, from about February 15, 1875, till after March 2, 1875; the second, from February 26, 1876, till after March 3, 1876; and the third, from about January 2, 1877, till after January 13, 1877. During these three journeys to Washington, did you stop at all on the way, either coming or going?

Ans. I do not think so, excepting so far as I may have gotten out of the train for refreshments at some station.

Int. 252. You have also mentioned your visit to Philadelphia during June 24 and June 25, 1876, when you were making ready for the exhibition of your telephones and other electric apparatus, and exhibiting them. Did you, on that occasion, go anywhere outside of Philadelphia, except in journeying to and from that city on the railroad train?

Ans. No. I did not go outside of Philadelphia on that occasion, excepting in journeying to and from that city.

Int. 253. Excepting the time when you were in Philadelphia to prepare for exhibiting and to exhibit your telephones and other electric apparatus, as mentioned, on June 24 and 25, 1876, did you ever set foot in the State of Pennsylvania, up to — say the year 1879?

Ans. No. I never set foot in the State of Pennsylvania, excepting upon the two days mentioned — June 24 and 25, 1876.*

* The reason for asking Mr. Bell whether, prior to 1879, he had ever been in Pennsylvania, outside of Philadelphia, except on June 24 and 25, 1876, was that the Government had called a witness who testified that Mr. Thomas A. Watson had told him, in 1875, that Mr. Bell had said that Drawbaugh's telephone was no more practical than the string telephone at Smith & Manning's stable in Salem, Mass. The same witness also said that Mr. Watson said that Drawbaugh's telephone "had been seen." There was no evidence as to who saw it, or where. Mr. Watson positively denied that he had ever made any such statements as those alleged by the Government's witness, and swore that he was never in Pennsylvania before the Centennial, and that he never heard of Drawbaugh until the summer of 1880, when the Drawbaugh scheme was proclaimed in the *Cincinnati Commercial*. The Supreme Court said (126 U. S. 562): "As we have read the testimony, it is not even pretended that he [Drawbaugh] took any of his instruments outside of his own village until May, 1878."

The Government's witness testified that there was a string telephone at Smith & Manning's stable in 1874. There was at one time a so-called string telephone at Smith & Manning's stable at Salem, but the defendants proved by the man who put it up, by the man who ordered it, and by the book-keeper who kept Smith & Manning's books, that the work was done and paid for in the spring of 1883. The string telephone superseded a tin speaking-tube, and the man who repaired the speaking-tube in January, 1883, testified that there was no string telephone there at that time. There was no further attempt on the part of the Government to prove any knowledge on the part of Mr. Bell or his associates, of any of Drawbaugh's work, and the Government made no attempt to corroborate its witness or to control the testimony which refuted him.

Int. 254. Are you acquainted with Daniel Drawbaugh, of Eberly's Mills, Cumberland County, Pennsylvania?

Ans. No. I am not acquainted with him, although I have seen him once.

Int. 255. When did you see the said Daniel Drawbaugh for the first time?

Ans. It was in Washington. He was pointed out to me among the audience, I think, either in the Supreme Court of the United States, while *The Telephone Cases* were being argued; or perhaps it might have been in some case being argued before the Commissioner of Patents in that city. I do not remember now, excepting that it was somewhere in Washington.

Int. 256. When did you first learn anything about Daniel Drawbaugh, or see his name written, or hear his name spoken?

Ans. On the 4th of August, 1880.

Int. 257. State the circumstances, and if you have any nearly contemporaneous memoranda by which to refresh your memory, you may refer to the same and state what they are.

Ans. On the 4th of August, 1880, just as I was leaving Washington for Boston, I received a visit from Mr. L. A. Bartlett, who was one of the partners in the firm of H. D. Cooke, Jr., & Co., bankers, of Washington. He informed me that a company was being formed in opposition to the American Bell Telephone Company, based upon the supposed claim of a man of the name of Daniel Drawbaugh to be the first original discoverer of the art of transmitting articulate speech by means of electricity. He stated that the owners of certain telephone patents issued to Klemm & Tisdell had paid Drawbaugh \$20,000 cash for his rights, and that as the check had passed through the bank of H. D. Cooke, Jr., & Co. he knew it was a *bona fide* transaction. He further stated that the banking house of H. D. Cooke, Jr., & Co. had thought of becoming interested in the company that was being organized under the Drawbaugh claims; but before investing he had consulted counsel upon the matter, and he showed me an opinion he had received. I had my clerk make a copy of the opinion, but he neglected to note the signature. I have reason to believe, however, that the opinion was written by Mr. Lysander Hill. Mr. L. A. Bartlett intimated to me that

perhaps I or the American Bell Telephone Company might desire to purchase a controlling interest in the stock of the company then being organized under the Drawbaugh claims, and he invited me either personally, or through an agent that I might appoint, to examine certain models of Mr. Drawbaugh's which he claimed were then in Washington or would shortly be there, and to investigate fully the claims of Mr. Drawbaugh. I had some correspondence with Mr. L. A. Bartlett upon the subject, in which he informed me that his firm had the option on three fifths of the stock of the company then being organized under the Drawbaugh claims; but that if I, or the American Bell Telephone Company desired to do anything in the matter it should be done at once, as he could not tell how long he might have such option. I have refreshed my recollection concerning these matters by reference to copies of letters and telegrams that were written at the time, and especially to a letter of my own which I wrote to Mr. Theodore N. Vail, general manager of the American Bell Telephone Company, on the 5th of August, 1880, the original of which I have now before me. In this letter I gave an account of the interview I had had with Mr. L. A. Bartlett in Washington the preceding day, August 4, 1880. This is how I fix that date as the time when I first heard the name of Daniel Drawbaugh.

Int. 258. Will you read your letter of August 5, 1880, to Mr. Theodore N. Vail, to which you have alluded, and make the same, as also the copy of the opinion which you believe to have been given by Mr. Lysander Hill, a part of your present answer?

[*Objected to by counsel for complainant as immaterial, irrelevant and incompetent.*]

Ans. The letter and copy of the opinion are as follows:

BRATTLE STREET,
CAMBRIDGE, MASS.,
August 5, 1880.

THEO. N. VAIL, Esq.,
Gen'l Manager Am. Bell Telephone Co.,
95 Milk Street, Boston.

Dear Sir,

Just as I was leaving Washington, yesterday, I received a visit from one of the partners of the firm of H. D. Cooke Jr. & Co.,

bankers, who informed me that a company is being formed in opposition to the American Bell Telephone Company, based upon the supposed claim of a man of the name of Dan'l Drawbaugh, to be the first and original discoverer of the art of transmitting articulate speech from one place to another by means of electricity. He stated that Drawbaugh had made and operated speaking telephones in 1868, but that being a poor man, imperfectly acquainted with the English language, and living quite out of the world in the centre of Pennsylvania, he had been unable to apply for Patents, &c. My informant stated that the owners of certain telephone patents, issued to Klemm & Tisdell, had paid Drawbaugh \$20,000, cash, for his rights, and that the check had passed through their bank — so that he knew that it was a *bona fide* transaction.

He further stated that the banking house of H. D. Cooke Jr. & Co. had thought of becoming interested in the Company that was being organized under the Drawbaugh claims, but before investing he had consulted counsel upon the matter, and he showed me the opinion he had received.

I told him that I could not, of course, express an opinion upon the matter as I knew nothing about it, but that, in the absence of fact, it appeared to me that it was simply an attempt to blackmail the American Bell Telephone Co., and that his firm would, in my opinion, be very unwise to invest any money in it.

My clerk made a copy of the opinion of counsel, which I beg to forward for your information. He neglected to copy the signature. The gentleman from whom I received this information promised to send me a copy of Drawbaugh's specification and claims. I will forward you a copy of the same when received.

Very truly yours,

ALEXANDER GRAHAM BELL.

[*Copy of Opinion.*]

MESSRS. H. D. COOKE & Co.

GENTLEMEN :

You ask me to give you an epitome of the condition of the Telephone inventions I represent.

Briefly the matters stand as follows :—

Four parties, assignees, own in equal proportions certain patents issued to Klemm and Tisdell for improvements in Telephone transmitters, receivers and induction coils — the same assignees own certain other improvements of the same inventors in the same line of art upon which applications for patents are pending. One of these is in interference, and they further own the right to other inventions of the same character for which applications will be made in due course.

Upon attempting to negotiate these patents and inventions counsel consulted came to the conclusion that although these inventions and

patents were exceedingly meritorious and were good in law, still they would be subordinate to patentees and inventors who control the broad right to transmit articulate sounds — vocal speech — by means of electricity. I concur in this view.

My clients asserted that they could produce certain other inventions which would remove the difficulty — in other words — that they could establish the fact that the claimants to the broad principle were anticipated. They founded their belief on two sources — on investigation in one direction it was discovered that the invention in question, a though valuable, related to the transmission of musical sounds, was limited thereto and was not capable of conveying articulate [speech], and the pursuit of this device (although it was exceedingly ingenious) was abandoned.

The second investigation resulted as follows: —

1. That Daniel Drawbaugh was the first and original discoverer of the art of transmitting articulate speech from one place to another by means of electricity, anticipating every one. In order to illustrate in part what he claims, I append a brief extract from his application now on file. The original covers 30 pages of manuscript and has 24 claims.

2. That he never abandoned the invention.

3. That his experimental and finished models, machines and instruments, which are now in my possession, fully illustrate the discovery and invention.

4. That there is an unbroken, cumulative chain of evidence establishing his rights to a patent or patents, — and this is supported by sworn evidence of seventeen persons, now in my possession, and by additional evidence of over seventy other witnesses cognizant of the fact, who have frequently seen Drawbaugh's machines operated, and heard them talked through, and who have themselves talked through them. All this anticipating every known claimant — dates and circumstances in addition to recorded evidence — confirm and strengthen the depositions in my hands.

After careful investigation of the law and the facts for over four weeks, I joined with two other colleagues in advising the purchase of the Drawbaugh inventions.

The assignees of the Klemm, Tisdell inventions followed this advice. I paid for them Twenty Thousand Dollars, cash, for the same, and assumed other liabilities, such as payment of all expenses, and agreement to deliver \$200,000 stocks of the consolidated patents and inventions. The purchase having been made, the assignment to the owners of the Klemm and Tisdell patents was executed, and the application and assignment filed. I should add that besides being the discoverer of the broad principle, Drawbaugh's apparatus and devices are exceedingly ingenious in many respects, but in some particulars, mechanical construction as shown by others is preferable; with the Klemm improvements probably there are no machines more

perfect. These will be of course contested, inside and outside of the Patent Office, — it is cheerfully invited, anxiously sought for, we have no fear of the results.

In the meantime it is equally clear that pending the consideration of the interference, which must be declared, no injunction will lie against the owners of the Drawbaugh invention.

The present four owners have mutually covenanted not to sell any portion of the patents or inventions, but that they shall be assigned to a corporation — the respective parties to receive a *pro rata* allotment of shares.

The option to about one-fifth of the gross shares is as I am advised taken up.

Respectfully —

WASHINGTON, D. C.

28 July, 1880.

Int. 259. Was the promised copy of Drawbaugh's specification and claims ever furnished to you or to the American Bell Telephone Company, so far as you know, or were the Drawbaugh models to which you have referred shown to you or, so far as you know, to the American Bell Telephone Company, until after they were put in evidence in the suit against the People's Telephone Company?

Ans. No. The promised copy of Drawbaugh's specification and claims was not furnished to me nor, so far as I know, to the American Bell Telephone Company, nor were the Drawbaugh models shown to me or to the American Bell Telephone Company, so far as I have any knowledge of the matter, before that litigation.

Int. 260. I suppose that the occasion when you, for the first time, saw Daniel Drawbaugh was long after 1880. Am I correct?

Ans. Yes. Years after that.

Int. 261. The name of Professor Sylvanus P. Thompson has been mentioned by Professor George F. Barker, a witness for the complainant in the present suit, in connection with the subject of the apparatus invented by Philip Reis, and called *the telephone*. Did you, during your sojourn in England between August 4, 1877, and November 10, 1878, become acquainted with Professor Sylvanus P. Thompson, and did he, in any letter addressed to you, refer to your invention of *the telephone*, as the electric speaking telephone has come to be named since the dates of your two patents here in suit?

Ans. Yes. I became acquainted with Professor Sylvanus P. Thompson in England, during the period mentioned; and he did, in a letter addressed to me, dated December 20, 1877 — the original of which is now before me — refer to my invention of the telephone.* In this letter Professor Thompson alluded to a letter he had addressed to the editor of the Journal of the Society of Arts, and he enclosed me a copy of that letter, apparently in his own handwriting, which is now before me.

[*Counsel for defendants puts in evidence a copy of the letters of Professor Sylvanus P. Thompson just referred to by the witness, and they are marked "Defendants' Exhibit Professor Sylvanus P. Thompson's Letters, H. L. H., Special Examiner."*]

Int. 262. Professor George F. Barker has also referred to an article by Professor W. F. Barrett, published in *Nature*, April 25, 1878, Vol. XVII., pp. 510 to 512, and relating to Philip Reis's telephone. Did you, during your sojourn in England, become acquainted with Professor W. F. Barrett, and did he favor you with any of his public declarations in respect to your own invention of the electric speaking telephone, and to the Reis apparatus, called "the telephone"?

Ans. Yes. I became acquainted with Professor W. F. Barrett, in England, during the period specified. Somewhere about the 12th of January, 1878, I received a letter from Professor Barrett, in which he alluded to some public remarks of his being incorrectly quoted in the public newspapers, and he enclosed to me a printer's proof of a paper by him "On the Telephone," that I might see for myself what he really had said. This printed proof is now before me, with a memorandum upon it in pencil, written by Professor Barrett, as follows:

"This was a paper recently read at a leading scientific society in Ireland. W. F. Barrett."

The paper purports to be from the Scientific Proceedings of the Royal Dublin Society. There are four pencil corrections upon the proof, which Professor Barrett stated in his letter he had made. Two of them are punctuation marks, and two are corrections of mis-spelling of words. The paper is stamped: "Proof 24/12/77," which I understand to mean the twenty-fourth day of December, 1877."

*Professor Thompson in his letter to Mr. Bell speaks of "Your beautiful and now classical instrument."

[*Counsel for defendants puts in evidence a copy of the paper just referred to by the witness, and it is marked "Defendants' Exhibit Barrett on the Telephone, H. L. H., Special Examiner."*]*

Int. 263. Since your invention of the electric speaking telephone, have you made and patented other inventions appertaining to electrical subjects, and, if so, will you mention the most notable one, and briefly explain its nature?

Ans. Yes. I have made and patented a number of inventions appertaining to electrical subjects. I think the most notable one is the invention described in letters patent No. 235,199, dated December 7, 1880, entitled "Apparatus for Signalling and Communicating, called 'Photophone.'" This, briefly, consists of an apparatus for transmitting articulate speech and other sounds to a distance by means of a beam of light; an apparatus by means of which, in fact, we can talk along a beam of light in the same sense that we now talk along a telegraph wire when we speak of transmitting speech by telephone. The apparatus takes advantage of the well known fact that the electrical resistance of crystalline selenium is affected by light, and that the diminution in resistance produced by illumination is proportional to the intensity of the light. When a piece of crystalline selenium arranged in a suitable receiver is placed in circuit with a telephone and a voltaic battery, the electrical current passing through the telephone is strengthened whenever the selenium is illuminated, because of the diminution of resistance occasioned in the selenium, and the current is strengthened in proportion to the intensity of the light falling upon the selenium. When, therefore, the intensity of the beam of light falling upon the selenium is varied in a manner proportional to the variations in the density of the air during the utterance of a sound, the strength of the electrical current passing through the telephone is also varied in a similar manner, and the telephone audibly produces a *facsimile* of that sound. I invented a transmitting apparatus which, upon being spoken to, caused the intensity of a beam of light to vary in the manner required; and this

* Professor Barrett described his paper as "Simply a brief description of an instrument which is destined to play an important part in the future of the human race." The paper is a description of Mr. Bell's "Articulating Telephone," and gives a brief summary of Mr. Bell's work.

varying beam of light falling upon the selenium of the receiver, which I also invented, caused the telephone to reproduce the utterance of the speaker, so that actual speech was transmitted from one place to another without any connecting wire between the places, the articulation being conveyed through the agency of an undulatory beam of light. Various improvements of the apparatus have been patented conjointly by myself and my associate, Mr. Sumner Tainter. I have transmitted musical tones by means of photophonic apparatus, from the top of the Franklin School Building, in Washington, to the hills to the north of Washington, a distance of about a mile and a quarter. I also transmitted articulate speech from the top of the Franklin School Building to a room—I think in L Street—a distance, I believe, of about 500 yards. Upon the occasion I refer to, Mr. Sumner Tainter operated the transmitter on the top of the Franklin School Building, and I received the beam of light in a parabolic reflector containing at its focus a selenium cell which was in circuit with a battery and a telephone. I placed the telephone to my ear, and when the beam of light entered the parabolic reflector, I heard the words, “Mr. Bell, Mr. Bell, if you hear what I say, come to the window and wave your hat.” The articulation at my ear was as loud and clear and distinct as if the words had been transmitted over an ordinary telephone line. The distance was too great to enable me to hear through the air anything of what Mr. Sumner Tainter said. I have successfully exhibited photophonic apparatus transmitting speech by means of a beam of light, publicly, in a number of places, both here and abroad, and a number of times.

[*Counsel for defendants puts in evidence the patent No. 235,199 of December 7, 1880, referred to by the witness, and the same is marked “Defendants’ Exhibit Bell’s Photophone Patent, H. L. H., Special Examiner.”*]

Int. 264. In your answer to Interrogatory 6 you described some early researches of yours relating to the double resonances of the mouth cavities when uttering vowel sounds. Does any early record exist which makes mention of those researches, and if so, what?

Ans. Yes. Mr. Alexander J. Ellis, to whom I communicated the results of my researches concerning the double resonances of the mouth cavities during the production of vowel sounds, published a

translation in English of Helmholtz's work, as mentioned in Interrogatory 7, and upon page 161 of that work, published in 1875, there is the following foot-note:

"[Mr. Graham Bell, son of Mr. Melville Bell, already mentioned (p. 157, Note), was in the habit of bringing out this fact by placing his mouth in the required positions and then tapping against a finger placed just in front of the upper teeth, for the higher resonance, and placed against the neck, just above the larynx, for the lower. He obligingly performed the experiment several times privately before me, and the successive alterations and differences in their direction were striking. The tone was dull and like a wood harmonica. Considerable dexterity seemed necessary to produce the effect, and I could not succeed in doing so. He carried out the experiment much further than is suggested in the text, embracing the whole nine positions of the tongue in his father's vowel scheme, and obtaining a double resonance in each case. — *Translator.*]"

Int. 265. In your preliminary statement in the *Harmonic Telegraph Interferences*, you said:

"It was just at this time [September or October, 1874] that I first heard of Mr. Elisha Gray. I received a note from my friend, Dr. Clarence J. Blake, in which he alluded to a letter received from Mr. Elisha Gray, descriptive of experiments made with Prof. Tyndall relative to the telegraphic transmission of vocal sounds. Dr. Blake stated his desire to show me the letter, and expressed his wish to have me meet Mr. Gray. I called upon Dr. Blake next day, and told him that as I was at that time applying for a caveat for an invention which would ultimately lead to the telephonic transmission of vocal sounds, I thought it might be well for me to be ignorant of Mr. Gray's researches until I had secured my patents. For this reason I did not see the letter, and I am still ignorant of its contents."

When did you for the first time see the letter from Elisha Gray to Dr. Clarence J. Blake, thus alluded to; what was its date, and how nearly did it correspond with the impressions you had derived from Dr. Blake's representations in his letter to you?

Ans. The letter referred to was put in evidence by Dr. Clarence J. Blake, during the course of his deposition in the *Harmonic Telegraph Interferences*, on the nineteenth day of February, 1877, and I saw for the first time either the original letter produced, or a copy of it, in the volume of that evidence. The letter referred to from Elisha Gray to Dr. Clarence J. Blake was dated "Royal Institution, London, October 2, 1874." Doctor Blake's letter to me, referred to

in my preliminary statement in the *Harmonic Telegraph Interferences*, was dated October 21, 1874. All this correspondence was again put in evidence during the cross-examination of Dr. Clarence J. Blake by Mr. Lysander Hill, in the suit of *American Bell Telephone Co. v. People's Telephone Co.**

In Doctor Blake's letter to me of October 21, 1874, he said :

"I have received a letter from the Royal Institute from Elisha Gray, concerning his experiments in telegraphing vocal sounds, which you will be glad to see."

This naturally alarmed me, as I was at work upon that subject, and I thought it best to decline to see Mr. Elisha Gray's letter, although Doctor Blake assured me that he had made a mistake, and that it had no reference to telegraphing vocal sounds. I did not, therefore, see Mr. Gray's letter at that time. I find from the published copy of Mr. Elisha Gray's letter to Doctor Blake of October 2, 1874, that the experiments to which Doctor Blake referred were alluded to in that letter as follows :

"I am engaged at present with Professor Tyndall and Latimer Clark in conducting some experiments partly as a matter of scientific interest, and partly with a view of certain practical applications."

There is no description in the letter of the nature of the experiments referred to. There was absolutely no warrant in the letter for the language used by Doctor Blake in his letter to me of October 21, 1874.

Int. 266. In your letter of March 2, 1877, to Elisha Gray, a copy of which has been put in evidence, you said :

"I do not know the nature of the application for a caveat, to which you have referred as having been filed two hours after my application for a patent, excepting that it had something to do with the vibration of a wire in water, and therefore conflicted with my patent."

How did you come to know that Elisha Gray's caveat "had something to do with the vibration of a wire in water," and just what was the full extent of your information on the subject, up to the date of your said letter of March 2, 1877?

* This was the so-called *Drawbaugh* case. Doctor Blake was called as a witness for the Bell Company. Mr. Lysander Hill was the leading counsel for the Drawbaugh interest.

Ans. An interference had been declared between the caveat of Mr. Elisha Gray referred to, and my application filed February 14, 1876, and this Interference was dissolved on the 25th of February, 1876. I reached Washington on February 26, 1876, after the dissolution of the Interference. At that time I knew nothing of the details concerning the Interference, nor of the exact points on which the Interference had been declared, and when I went to the Patent Office for the purpose of explaining to the Examiner the exact points of difference between the invention shown in my application filed February 14, 1876, and that described in my prior application filed February 25, 1875, as stated in my answer to Interrogatory 108, I took the opportunity, while in the Patent Office, of referring to the Interference with the caveat of Mr. Gray, which had just been dissolved. As I knew nothing of the matter, I asked the Examiner what the point of interference had been. He told me that a caveat was a confidential document, and he therefore declined to show it to me, and I did not see the caveat nor any part of it, but the Examiner indicated in a general way the point of interference, by pointing to a paragraph in my application of February 14, 1876, with which I understood him to say the caveat had conflicted. It was a paragraph in the body of the specification, and read as follows :

“Undulations are caused in a continuous voltaic current by the vibration or motion of bodies capable of inductive action, or by the vibration of the conducting-wire itself in the neighborhood of such bodies. Electrical undulations may also be caused by alternately increasing and diminishing the resistance of the circuit, or by alternately increasing and diminishing the power of the battery. The internal resistance of a battery is diminished by bringing the voltaic elements nearer together, and increased by placing them farther apart. The reciprocal vibration of the elements of a battery, therefore, occasions an undulatory action in the voltaic current. The external resistance may also be varied. For instance, let mercury or some other liquid form part of a voltaic circuit, then the more deeply the conducting-wire is immersed in the mercury or other liquid, the less resistance does the liquid offer to the passage of the current. Hence, the vibration of the conducting-wire in mercury or other liquid included in the circuit occasions undulations in the current. The vertical vibrations of the elements of a battery in the liquid in which they are immersed produce an undulatory action in

the current by alternately increasing and diminishing the power of the battery."

The Examiner simply pointed to this paragraph in my specification and said that the caveat had conflicted with that. I think I asked him whether the exact point of interference lay in the latter part of the paragraph describing how the external resistance may be varied, and he answered affirmatively. At all events, I carried away the impression that the caveat had conflicted with that part of the paragraph where I spoke of mercury or some other liquid forming part of a voltaic circuit so that the more deeply the conducting-wire was immersed in the mercury or other liquid, the less resistance would the liquid offer to the passage of the current. This was all the information I ever had concerning the caveat of Mr. Elisha Gray, until the publication of Mr. George B. Prescott's book alluded to in my answer to Interrogatory 225. I do not know what it was that led me to imagine that the caveat had something to do with the vibration of a wire in *water*, unless, indeed, it might have been due to the fact that the liquid I had in contemplation when I first wrote the paragraph from my specification quoted above, was water, and not mercury, as stated in that paragraph; and to the fact that I had previously experimented with water in my spark-arrester. As I have already stated in my answer to Interrogatory 103, it was the contemplation of the operation of this spark-arrester that led me to the invention of the mode of varying the external resistance of the circuit, in the manner described in the paragraph from my specification quoted above.

Int. 267. On the occasion when you delivered your lecture of October 31, 1877, before the Society of Telegraph Engineers, at London, England, did any other proceedings take place besides the delivery of your said lecture, and if so, what?

Ans. Addresses or remarks were made by the president, Professor Abel, by Mr. Latimer Clark, and by Mr. William H. Preece. These remarks were published with my lecture, in the *Journal of the Society of Telegraph Engineers*, in 1877, a copy of which is now before me.

[*Counsel for defendants puts in evidence a copy of the remainder of the record of the meeting at which the lecture of the witness was de-*

livered, and it is marked "Defendants' Exhibit Proceedings at Bell's London Lecture, H. L. H., Special Examiner."] *

Int. 268. Who were Mr. Latimer Clark and Mr. William H. Preece mentioned in the record, a copy of which has just been put in evidence?

Ans. They were very well known electricians. Mr. Latimer Clark was, I think, connected with the laying and operation of Atlantic telegraph cables, and Mr. William H. Preece was Superintendent of the Telegraphic System of Great Britain—the electrical head of the Postal Telegraph Department.

Int. 269. In your answer to Interrogatory 198 you read from the original of an invitation by several gentlemen to give a practical exhibition of your electric speaking telephone, such invitation being dated April 20, 1877. Will you state the professional or official positions of those gentlemen at that time?

Ans. The professional or official positions, at that time, of those gentlemen who signed the invitation, were as follows:

Benjamin Peirce, Perkins Professor of Astronomy and Mathematics, Harvard College.

Joseph Lovering, Hollis Professor of Mathematics and Natural Philosophy, Harvard College.

* Professor Abel, the President of the Society, introduced Mr. Bell, who delivered the so-called London lecture. At the close of the lecture the president said that he should be "glad to hear the opinions of men eminent for their knowledge of physical science, of whom there were many in the room." Mr. Latimer Clark then proposed a vote of thanks to Mr. Bell, and made some remarks in which he said that since his connection with the Society there had never been a subject brought before them so interesting or so important as the one of which they had just heard or one which would mark a greater epoch in the history of electricity. Mr. W. H. Preece seconded Mr. Clark's proposition, and in the course of his remarks spoke of Mr. Bell's allusion to the fact that expectancy sometimes led him to anticipate what was said through his early telephone. Mr. Preece said that he himself had recently exhibited the telephone before a very large audience including many learned men. He selected "one of the leading scientific men of the day" and placed the telephone in his hand, expecting to hear from his lips some words of special wisdom. The sage shouted through the telephone "Hi diddle diddle—follow up that." Then putting the telephone to his ear for the response, he stated with great satisfaction, "He says—The cat and the fiddle." The person who was supposed to have made the answer was fifty miles away. The next day Mr. Preece met him and asked him if he understood the "Hi diddle diddle." The man said "No; I asked him to repeat."

E. N. Horsford, formerly Rumford Professor and Lecturer on the Application of Science to the Useful Arts, Lawrence Scientific School, Harvard University.

Henry W. Longfellow, formerly Smith Professor of the French and Spanish Languages, and Professor of *Belles Lettres*, Harvard College.

George B. Emerson, Fellow of the American Academy.

Oliver Wendell Holmes, Parkman Professor of Anatomy, Medical School of Harvard University.

Charles W. Eliot, President of Harvard University.

Alexander H. Rice, Governor of the Commonwealth of Massachusetts.

Nehemiah Gibson, Alderman of the City of Boston.

Frederick O. Prince, Mayor of the City of Boston.

William F. Warren, President of Boston University.

John D. Runkle, Professor of Mathematics, Massachusetts Institute of Technology.

Charles Francis Adams, formerly United States Minister Plenipotentiary to Great Britain.

Wolcott Gibbs, Rumford Professor and Lecturer on the Application of Science to the Useful Arts, Lawrence Scientific School, Harvard University.

Edward C. Pickering, Director and Phillips Professor of Astronomy at the Observatory, Harvard University.

Int. 270. In your answer to Interrogatory 103, referring to the magneto-electric apparatus conceived by you in the summer of 1874, for the transmission and reproduction of articulate speech, you stated that you were impressed by the idea that electrical impulses generated in such apparatus by the voice itself would be too feeble for practical use on *real lines*. Elsewhere you have spoken of your early endeavors to adapt your electric speaking telephones for practical use upon *real lines*. What, precisely, have you meant in these connections by the term "real lines"?

Ans. I meant, in these connections, lines that were actually in use for business or commercial purposes. I meant out-door lines connecting places at considerable distances from one another, and actually used for purposes of communication, in contradistinction

to artificial lines used only experimentally in the laboratory. My remarks had reference to the commercial use of the telephone for business and other purposes.

Int. 271. Aside from your own out-of-door lines for experiment and exhibition, when was the first electric speaking telephone line established, and between what places?

Ans. The first telephone line was opened in Boston on the 4th of April, 1877. It connected the office of Mr. Charles Williams, Jr., 109 Court Street, Boston, with his residence in Somerville, Mass. The opening of this line was noticed in the following Boston papers published April 5, 1877: *Daily Advertiser*, *Post*, *Daily Globe*, *Herald*, and *Traveler*. I quote from the *Boston Daily Globe* of Thursday morning April 5, 1877, the following:

“PERFECTING THE TELEPHONE.

Professor A. Graham Bell, the inventor of the telephone, had the pleasure of assisting yesterday at the opening of the first regular telephonic line in the world—a private line between the place of business of a gentleman in this city and his residence in Somerville. The instruments worked admirably, and the enterprising gentleman is very much pleased with his private telephonic wire between town and home. The practical value of Professor Bell's invention is being newly proved every day.”

The slip from which I have just read I cut from the newspaper at the time and pasted in my scrapbook, and it is now before me.

Int. 272. In the course of your present deposition you have frequently given the exact dates of certain events testified about. Have you, in any such case, relied upon unaided memory alone?

Ans. No. While I have been able from unaided memory alone to recall the fact of the events themselves, I have been unable to fix dates excepting by reference to contemporaneous memoranda. I think in all cases in which I have given exact dates, I have refreshed my memory by reference to written or printed memoranda which were contemporaneous or nearly contemporaneous with the events.

Int. 273. When, on January 20, 1876, you made oath to the specification which accompanied your application filed in the Patent Office of the United States, February 14, 1876, and while that application was pending, and at the date when your patent No. 174,465, of March 7, 1876, was granted, what was the state of your knowl-

edge in respect to your being a true and original inventor of each and all of the "Improvements in Telegraphy" described and claimed in that specification, as amended and annexed to that patent and made a part thereof; and what was then your belief as to your being the first inventor of each and all of the "Improvements in Telegraphy" so described and claimed as of your invention?

Ans. When, on January 20, 1876, I made oath to the specification which accompanied my application filed in the Patent Office of the United States, February 14, 1876, and while that application was pending, and at the date when my patent No. 174,465, of March 7, 1876, was granted, I knew that I was a true and original inventor of each and all of the "Improvements in Telegraphy" described and claimed in that specification, as amended and annexed to that patent and made a part thereof, and I believed that I was the first inventor of each and all of the "Improvements in Telegraphy" so described and claimed as of my invention.

Int. 274. When, on January 20, 1876, you made oath to the specification accompanying your application, which resulted in the issue of patent No. 174,465, of March 7, 1876, and when, on February 14, 1876, that application was filed in the Patent Office, did you know or believe, or had you any reason to believe, that any one else claimed to have made, or pretended to have made, the inventions, or any or either of them, described and claimed in that specification, or had any one to your knowledge or within your information, up to that time, asserted or suggested that your said inventions, or any or either of them, had been originated or discovered by any other person or persons whomsoever, or had been described in any patent or printed publication?

Ans. No.

Int. 275. When, on January 13, 1877, you made oath to the specification which accompanied your application filed in the Patent Office of the United States, January 15, 1877, and while that application was pending, and at the date when your patent No. 186,787, of January 30, 1877, was granted, what was the state of your knowledge in respect to your being a true and original inventor of each and all of the "Improvements in Telephony" described and claimed in that specification, as annexed to that patent and made a part

thereof, and what was then your belief as to your being the first inventor of each and all of the "Improvements in Telephony" so described and claimed as of your invention?

Ans. When, on January 13, 1877, I made oath to the specification which accompanied my application filed in the Patent Office of the United States, January 15, 1877, and while that application was pending, and at the date when my patent No. 186,787, of January 30, 1877, was granted, I knew that I was a true and original inventor of each and all of the "Improvements in Telephony" described and claimed in that specification, as annexed to that patent and made a part thereof; and I believed that I was the first inventor of each and all of the "Improvements in Telephony" so described and claimed as of my invention.

Int. 276. When, on January 13, 1877, you made oath to the specification accompanying your application which resulted in the issue of patent No. 186,787, of January 30, 1877, and when, on January 15, 1877, that application was filed in the Patent Office, did you know or believe, or had you any reason to believe, that any one else claimed to have made, or pretended to have made, the inventions, or any or either of them, described and claimed in that specification, or had any one to your knowledge or within your information, up to that time, asserted or suggested that your said inventions, or any or either of them, had been originated or discovered by any other person or persons whomsoever, or had been described in any patent or printed publication, excepting only what you had learned sometime after Christmas, 1876, concerning the suggestions made by Professor Amos E. Dolbear, as mentioned in your answers to Interrogatories 227, 228 and 229?

Ans. No.

Int. 277. What special public honors have been conferred upon you in recognition of your invention of the electric speaking telephone?

Ans. A great many public honors have been conferred upon me in recognition of my invention of the electric speaking telephone. I have never attempted to make a list of these honors, and it is impossible for me at the present time to enumerate them. It so happens that I have no residence in Washington, as the house I am building there

is not yet completed. My papers and memoranda are scattered in different places, so that it is impracticable for me just now to collect together papers relating to the subject inquired about. I shall feel much obliged if I can be excused from making an attempt to give a complete account of the public honors conferred upon me, for I should be very sorry to seem to show lack of appreciation by forgetfulness in any case. I cannot give a correct account of these honors from unaided memory alone.

Int. 278. I believe that certain public honors have been bestowed upon you by the French Government, in recognition of your invention of the electric speaking telephone. Will you speak particularly of these?

Ans. As a recognition of my invention of the electric speaking telephone, I have received from the French Government the Volta prize of 50,000 francs. This amount was appropriated for me by special act of the French Legislature. The Volta prize was founded by the first Napoleon in 1802, about the time of the visit of Alessandro Volta to France. In the *Mémoires de L'Institut National Des Sciences et Arts*, Volume 5, published at Paris in the year 1804, is an account of the prize founded in the year 1802, by the First Consul, Bonaparte, for discoveries relating to electricity and galvanism. In Bonaparte's letter to the Minister of the Interior, founding the prize, he stated :

“Je désire donner en encouragement une somme de soixante mille francs à celui qui, par ses expériences et ses découvertes, fera faire à l'électricité et au galvanisme un pas comparable à celui qu'ont fait faire à ces sciences Franklin et Volta, et ce au jugement de la classe.

Les étrangers de toutes les nations seront également admis au concours.”

I translate this as follows :

“I desire to give the sum of sixty thousand francs as an encouragement to him, who by his experiments and discoveries, shall make in electricity and galvanism, a step comparable to that which has been made in those sciences by Franklin and Volta, and this to be decided by the proper section in the Institute.

Foreigners of all nations shall be admitted equally to the competition.”

The Volta prize was revived by the Emperor Napoleon III, as a prize of 50,000 francs, and was continued under the Republic.

An account of the special award of this prize to me is contained in *L'Année Scientifique et Industrielle*, by Louis Figuier, for the year 1880, published in Paris in 1881, pages 74–78, a copy of which is now before me.

[*Counsel for defendants puts in evidence a copy, accompanied with a translation of the publication last referred to by the witness, and it is marked "Defendant's Exhibit Account of Bell's Volta Prize, H. L. H., Special Examiner."*]*

The French Government has also decorated me — creating me an Officer of the Legion of Honor.

Int. 279. Did you compete for the Volta prize, in the sense of becoming an applicant therefor, or was it conferred upon you spontaneously?

Ans. It was conferred upon me spontaneously. I knew nothing about it until I was notified that the grant had been made by the French Legislature.

Int. 280. There is one other honor which I wish you would mention. I understand that the University of Heidelberg, on the occasion of the celebration of the five hundredth anniversary of its founding, conferred upon you a degree, in recognition of your invention of the electric speaking telephone. Was that the fact, and if so, when was it conferred, and if you have a copy of it, please produce the same.

Ans. Yes. That was the fact. The University of Heidelberg conferred upon me the degree of Doctor of Medicine, August 5, 1886. I have here a photo-lithographic reproduction, one-fourth size, of the original diploma.

[*Counsel for defendants puts in evidence the photo-lithographic copy of the diploma mentioned, and it is marked "Defendants' Exhibit Bell's Heidelberg Diploma, H. L. H., Special Examiner."*

Counsel for defendants also puts in evidence a translation of the same as part of the exhibit so designated.]

Int. 281. What use of your magneto-electric speaking telephone has been made in surgery, and to what extent has it come to be recognized as a valuable contribution to medical science?

* The first award of the Volta prize was to Ruhmkorff in 1864 for the induction coil. The next award was to Mr. Bell.

Ans. My magneto-electric speaking telephone is used in surgery in connection with a form of induction-balance devised by me for the purpose of locating the position of bullets or other metallic masses lodged in the human body, without pain or suffering to the patient. It is also used in connection with the telephonic probe invented by me, as another means of determining the position and depth of metallic masses imbedded in the human body. My telephonic probe consists simply of a needle which is metallically connected with one terminal of an ordinary commercial hand-telephone. The other terminal is connected to a steel plate which is placed in the patient's mouth, or placed in contact anywhere with the moistened skin of the patient. When the needle is thrust through the flesh of the patient, the telephone emits a very perceptible click at the moment the point of the needle makes contact with the leaden bullet. Under such circumstances a weak voltaic battery is formed within the body of the patient. The two metals composing the battery are respectively, the lead of the bullet and the steel plate applied to the skin, and the body itself contains the liquid between them. Before contact with the leaden bullet little or no electrical effect is produced, because the needle and the plate are formed of the same metal. When the needle makes contact with bone, no sound is produced in the telephone. The telephonic probe is now well known in surgery, and is used in hospital practice both in this and other countries. The induction-balance is also known, but is not so generally used on account of its complexity. It requires a greater knowledge of electricity on the part of the surgeon than the telephonic probe, and is not so reliable in its indications.

Int. 282. In your answer to Interrogatory 122 you described the electric speaking telephone instruments which you exhibited at the Centennial Exhibition on Sunday, June 25, 1876, and designated them as follows :

Centennial Single-pole Magneto Telephone.
Centennial Double-pole Magneto Telephone.
Centennial Liquid Transmitter.
Centennial Iron-Box Receiver.

Are these instruments still in existence ; and if so, where are they at the present time ; and in what condition of completeness ?

Ans. These instruments are in existence, and they are now on the table before me.* The membranes and armatures of the magneto instruments are missing, although portions of the membranes remain. The extremity of one of the japanned tin mouth-pieces is also missing. The membrane of the Centennial Liquid Transmitter with attached rod is missing, with some of the screws to hold the apparatus together. The japanned tin mouth-piece of the Liquid Transmitter is not in the original condition as used in the Centennial Exhibition; notches having been cut in the edges to make it serve some other purpose. The lid of the Centennial Iron-Box Receiver is missing, and the instrument is not in the condition in which it was at the time of the Centennial Exhibition. There were no holes in the side of the iron cylinder, where now there are four; and the coil inside is not the original one, but some coil used in subsequent experiments after the Centennial.

Int. 283. In your answer to Interrogatory 133, you described a diaphragm of Tagger's iron, made about the end of June, 1876, and used June 30, 1876, and thereafter. Is that Tagger's iron diaphragm, mounted as shown in your picture of it, still in existence; and if so, in what condition?

Ans. It is still in existence, and it is before me on the table. The condition is just as shown in the picture put into my answer to Interrogatory 133, excepting that the diaphragm is not now perfectly flat, but has been dented.

Int. 284. In your answer to Interrogatory 147, you referred to a two-pole electro-magnet with permanently-magnetized cores, made about the middle of July, 1876, and used thereafter; and you inserted a picture of it, reduced in size, in your answer to Interrogatory 147. Is that electro-magnet still in existence; and if so, what is its condition?

Ans. Yes. That electro-magnet with permanently-magnetized cores is still in existence, and it is now on the table before me. The condition is as shown in the picture. So far as I can judge, it is in perfect condition. From lack of an armature, after so many years, the magnetic condition is considerably enfeebled; but the cores are still permanently magnetized, and it is a pretty good permanent

* The instruments are now (1908) in the National Museum at Washington.

magnet yet, although of course it was more powerful in the past than now.

Int. 285. Were each and all of these six devices, to wit, the four Centennial instruments, the Tagger's iron diaphragm, and the permanently-magnetized electro-magnet, in evidence as exhibits in the telephone suits which were heard and decided, on appeal, by the Supreme Court of the United States?

Ans. They were. They were introduced in evidence in the *Dowd* case, and subsequently, in the *People's Telephone Company* case; and I think in other cases.

[*Counsel for defendants request the Examiner to mark these six devices for further identification, and states that while he does not introduce them in evidence formally as exhibits, to be put into the custody of the Examiner, they will be produced before the Court at the hearing of the present case, and will be produced at all reasonable times for the inspection of counsel for complainant and of such experts as he may designate.*

The Examiner puts upon the tags attached to the several exhibits his initials, official designation, and the present date.]

Cross-Examination by CHARLES S. WHITMAN, Esq., *of Counsel for Complainant.*

Cross-Int. 286. You say, Mr. Bell, in answer to the third interrogatory, that you gave testimony in *The Speaking Telephone Interferences* in Washington in the year 1881. How many speaking telephone interferences were there in which your patents were involved? You will observe that my question relates only to the speaking telephone interferences.

Ans. My patents No. 174,465, of March 7, 1876, and No. 186,787, of January 30, 1877, were involved in Interferences A, B, C, E, F, G, I, J and L.

Cross-Int. 287. How many preliminary statements were filed by you in these interferences?

Ans. There were two preliminary statements, both of which have been put in evidence. The first of these was used in Interferences A, B, C, E, F, G and L, and the second in Interferences I and J.

Cross-Int. 288. Then, if I understand you correctly, the statements which have been introduced in evidence and marked "Defendants' Exhibit Bell's Preliminary Statements in Speaking Telephone Interferences" were the only preliminary statements which were filed by you in *The Speaking Telephone Interferences*. Am I correct?

Ans. I believe so.

Cross-Int. 289. You say, in answer to Interrogatory 3, that in addition to your testimony in cases referred to in the preceding answer, you have executed several affidavits in various telephone suits. Please give the titles of these suits, if you recollect them?

Ans. I do not recollect the titles, but I can obtain them for you, if you so desire. Substantially the same affidavit was used in nearly all the cases where a preliminary injunction was asked for by the American Bell Telephone Company.

Cross-Int. 290. You say in answer to Interrogatory 5 that you were educated at the Royal High School of Edinburgh, Scotland, and passed through the whole curriculum of that school; that you attended lectures on classical subjects for one year at the Edinburgh University; that you attended a course of anatomy at the University College, London; and that you matriculated as an undergraduate of the London University, you think, in the year 1867. What course of study did you pursue concerning electricity and its applications at these institutions, and what books were used as text-books?

Ans. I did not pursue any course of study concerning electricity and its applications at the Royal High School of Edinburgh, the Edinburgh University, or University College in London. In regard to the London University — attendance upon lectures was not required, but examinations were annually held, for which persons could prepare themselves by private study. I think, but am not quite sure at this present date, that some knowledge of electricity was required for matriculation. If so, I acquired the requisite knowledge privately, but what were the text-books used, I cannot now state.

Cross-Int. 291. I suppose you used as text-books the works on physics which were prescribed in the courses of study of these institutions, did you not?

Ans. I do not think I did. I rather think the books I used were such as I could pick up at old bookstores. I do not mean to say that it may not be possible that I may have read some of the text-books on physics used at these institutions, but I cannot assert so positively. My knowledge of electrical subjects was not acquired in a methodical manner, but was picked up from such books as I could get hold of, and from such experiments as I could make with my own hands.

Cross-Int. 292. Do you remember the books relating, in whole or in part, to electricity, or the applications of electricity, which you consulted or studied at the time you were in attendance upon the institutions of learning to which you refer?

Ans. No. I probably read something on the subject of electricity and its applications at that time, but only in a desultory manner, and I cannot now remember the names of any of the books consulted at that period. It was not until after my interview with Mr. Ellis, in London, that I really took up the study of the subject of electricity.

Cross-Int. 293. I understand you to say, in answer to Interrogatory 6, that from your earliest childhood your attention was specially directed to the subject of acoustics, and specially to the subject of speech, and that you were urged by your father to study everything relating to these subjects, as they would have an important bearing upon what was to be your professional work. What work, or works, relating in part or in whole to acoustics, did you study or use at the time referred to in your answer to Interrogatory 6?

Ans. While a boy, I read all the books that my father had in his library upon these subjects. I do not remember the names of the works upon sound that he possessed, but I remember in relation to speech, I studied, as a boy, my father's and grandfather's works upon speech, also *The Real Character*, by Bishop Wilkins, published about 1680; *Prosodia Rationalis*, by Joshua Steele; *Le Mécanisme de la Parole*, by Baron de Kempelen, giving a full description and plates of his celebrated automaton speaking machine. This last work was lent to my father by Sir Charles Wheatstone, and Sir Charles Wheatstone himself showed me, before I came to this country, a reproduction of Baron de Kempelen's speaking machine which he had

made, and I saw it operated by his own hands and heard it speak. I may say I have not thought of this subject inquired about for very many years, and I cannot pretend to remember the names of all the books upon speech that I read when a boy; but as I reflect upon the subject, a number of books recur to my mind, and I have no doubt that if you desire further information, I could, upon reflection, remember the precise titles of quite a number of other works. My father, of course, from his profession, was in the habit of collecting works upon the subject of speech, and I read all that he had in his library. After I left home I had not so many opportunities for consulting works on acoustics and speech, but I made a point of reading all that fell in my way, and of collecting such works into my own library. The period of time referred to in my answer to Interrogatory 6 relates to the time before I came to this country. It is difficult for me, at the present time, to distinguish the books on acoustics and speech that I read before coming to this country from those that I have seen since. I may say, however, that I had exceptional advantages before coming to this country for knowing of works on speech, and I probably was acquainted with a considerable portion of the literature upon that subject. I had not the same advantages of knowing of works on acoustics and general physics until after my arrival in America.

Cross-Int. 294. You also say in answer to the 6th Interrogatory, that your father encouraged you to experiment, and offered a prize to his sons for the successful construction of a speaking machine, that you made a machine of this kind, as a boy, and were able to make it articulate a few words. Was this speaking machine to which you refer an electrical contrivance or apparatus?

Ans. No. It was a direct imitation of the vocal organs themselves. I made a model from a human skull, in gutta-percha, and filled in the soft parts of the mouth with india-rubber stuffed with cotton batting. Upon blowing a current of air through the artificial larynx, a voice-like sound was produced, and upon operating the artificial lips and tongue, quite a number of words were distinctly pronounced. Portions of this apparatus are still in existence.

Cross-Int. 295. Was this speaking contrivance referred to by you in your last answer an invention of your own, or was it an imitation of something that had been before illustrated or described?

Ans. It was an invention of my own.

Cross-Int. 296. Do you refer, in your whole answer to Question 6, to any invention or discovery of your own which was not before known in this country, or described in printed publications in foreign countries?

Ans. Yes. A good deal of what I referred to in that answer was known before I discovered it, although I was not aware of the fact until after my own discoveries had been made; but there are some points touched upon that I think were really original with myself, and were not before known in this country or described in printed publications in foreign countries.

Cross-Int. 297. Cross-interrogatory 292 related particularly to works relating in part or in whole to electricity or the applications of electricity. Do you remember, this morning, any works relating to electricity or the applications of electricity, which you studied or consulted before coming to this country? If so, be kind enough to mention them.

Ans. It has come to my remembrance that among the earliest books I consulted containing information concerning electrical matters was a series of octavo volumes published, I think, by Chambers, of Edinburgh. I am not quite certain of the title of the work, but think it was called *A Library of Useful Information*, or *A Library of Useful Knowledge*. My father possessed a copy of this work, and I now remember that I found it a perfect mine of information upon scientific subjects, including, I think, acoustics, as well as electricity and telegraphy. I may also add that about the year 1868 I was a reader at the British Museum library, but I cannot now pretend to remember the works I consulted on electricity and acoustics.

Cross-Int. 298. In your answer immediately preceding the adjournment Saturday, you say that a great deal of what you refer to in your answer to Interrogatory 6 was known before you discovered it, but that there were points touched upon in your answer to Interrogatory 6 that you think were original with yourself. Will you please be kind enough to distinguish between what was known before you discovered it, and what was original with yourself?

Ans. It was known before I discovered it, that vowel quality was produced by the resonance tones of the mouth-cavities mingling

faintly with the tone of the voice; but the method of examining the pitches of the mouth-cavities described by me in answer to Interrogatory 6, I think was original with myself. Automaton speaking machines also were known before I made one; but the particular form of speaking machine constructed by me, as a boy, I think was original with myself.

Cross-Int. 299. You refer, in your answer to Question 293, to Sir Charles Wheatstone. Were you, before you came to this country, familiar with any apparatus for transmitting speech invented, constructed, or used by Sir Charles Wheatstone?

Ans. I do not know that I ever heard of the transmission of speech by Sir Charles Wheatstone. I have read or heard of experiments made by him in transmitting the tones of a piano mechanically through a wooden rod, and audibly reproducing them to an audience, by means of a violin or sounding-board placed against the end of the wooden rod. I do not know whether I knew of this before I came to this country or not. It is probable that I did. I am not quite sure, either, whether I attributed this experiment to Sir Charles Wheatstone or to Professor Tyndall, for I became aware of the fact that Professor Tyndall had performed experiments of this character before public audiences in the Royal Institution at London. It is probable that I knew of this before I came to this country, but I cannot be perfectly sure.

Cross-Int. 300. Was the principle and acoustical mode of operation of Wheatstone's apparatus to which you have referred, the same as that of the acoustical toy known as the lovers' telegraph or telephone?

Ans. Substantially the same. There is a slight difference, because a wooden rod will transmit pushes as well as pulls. The mode of operation thus more closely resembles the method of transmitting sound-vibrations mechanically through metallic wires, described by Hooke in a paper published about two hundred years ago.

Cross-Int. 301. When did you first become acquainted with the paper by Hooke referred to in your last answer?

Ans. Not until after the issue of my two patents, No. 174,465, of March 7, 1876, and No. 186,787, of January 30, 1877.

Cross-Int. 302. When was your attention first directed to the

lovers' telegraph or telephone, and when did you first understand its acoustical mode of operation?

Ans. I never heard of the lovers' telegraph until after the issuance of my patent No. 174,465, of March 7, 1876. In the year 1876, what was called "the lovers' telegraph" was sold in the streets of Boston. This was the first time my attention was directed to the lovers' telegraph or telephone, and I understood its acoustical mode of operation the moment I saw it.

Cross-Int. 303. Will you be kind enough to fix, as nearly as you can, the exact date of your first acquaintance with the lovers' telegraph, either by unaided memory or by reference to any contemporaneous memoranda?

Ans. I think it must have been after the 11th of September, 1876. At all events, it was while I was living at No. 5 Exeter Place, Boston. I remember seeing men hawking the lovers' telegraph in the streets, and I immediately purchased one and took it up to No. 5 Exeter Place, and tried it with Mr. Watson, and was very much interested in its mode of operation. I feel pretty sure it was after the 11th of September, but I do not like to make the assertion positively. This is as closely as I can approximate to the exact date.

Cross-Int. 304. Will you please describe the construction and mode of operation of this lovers' telegraph which you purchased in Boston, referring particularly to the diaphragms which were used, and the acoustical mode of operation of the diaphragms?

Ans. The apparatus consisted essentially of two membranes, each stretched over the end of a short tube, and connected together by a tense string. Through the intermediary of the stretched string the one membrane was enabled to pull the other membrane and control its motion in every phase. If any person uttered a sound in the neighborhood of one of the stretched membranes, the membrane was thereby caused to vibrate, copying the form of the aerial vibration accompanying the sound. This transmitting membrane in vibrating pulled the distant membrane with a varying force through the intermediary of the stretched string, and caused the distant membrane to copy the form of vibration of the transmitting membrane, and thus occasion aerial vibrations at the receiving end similar in form to

those at the transmitting end ; so that an ear placed near the receiving membrane perceived a sound of similar kind to that uttered in the neighborhood of the transmitting membrane. In Cross-interrogatory 302 you have referred to this apparatus for the mechanical transmission of articulate speech as a *telephone*. When I first heard of the apparatus, it was not known by that name, but was always termed the "lovers' telegraph" or "thread telegraph."

Cross-Int. 305. In my last question, I applied the word "telephone" to the string instrument, on what I then supposed and now suppose to be the excellent authority of Sir Charles Wheatstone, as I find it stated in Preece's book, *The Telephone* :

"In the 'Repository of Arts,' September 1, 1821, we read a description of an instrument which Wheatstone invented, and called a *telephone*."

I will, therefore, in further questions continue to use this mode of expression, and will now ask you when you first saw or used a lovers' telephone or telegraph having metal diaphragms?

Ans. I am not conscious of having ever seen a lovers' telegraph or telephone with metal diaphragms, excepting so far as I may, perhaps, myself, have tried experiments with tin cans or something of that sort, connected by a string.

Cross-Int. 306. Please carry your statement a little farther and state when and where you experimented with tin cans and a string.

Ans. I do not know. I am not sure whether I really ever did myself personally experiment with tin cans and a string. I remember making experiments with cigar boxes connected by a string, in Canada, probably about Christmas time, 1876, or possibly at some later period.

Cross-Int. 307. You mean, I suppose, that these cigar boxes were provided with wooden diaphragms?

Ans. Yes.

Cross-Int. 308. You have referred to a statement or communication by Robert Hooke. I find in Mr. Preece's book, *The Telephone*, the following statement :

"Robert Hooke, in 1667, described how, by the help of a tightly-drawn wire, bent in many angles, he propagated sound to a very considerable distance.

‘‘Tis not impossible,’ he says, ‘to hear a whisper at a furlong’s distance, it having been already done; and perhaps the nature of the thing would not make it more impossible, though that furlong should be ten times multiply’d. And though some famous authors have affirm’d it impossible to hear through the thinnest plate of Muscovy glass; yet I know a way by which ’tis easie enough to hear one speak through a wall a yard thick. It has not yet been thoroughly examin’d how far Otacousticons may be improv’d, nor what other wayes there may be of quick’ning our hearing, or conveying sound through other bodies than the air; for that that is not the only medium I can assure the reader, that I have, by the help of a distended wire, propagated the sound to a very considerable distance in an instant, or with as seemingly quick a motion as that of light, at least incomparably quicker than that which at the same time was propagated through the air; and this not only in a straight line, or direct, but in one bended in many angles.’”

Was this the communication or article to which you referred in your answer?

Ans. Yes. This is taken from that communication. I cannot tell without looking at the original whether it is the whole of it or not.

Cross-Int. 309. In your patent No. 174,465, you use the following language:

“The armature *c*, Fig. 7, is fastened loosely by one extremity to the uncovered leg *d* of the electro-magnet *b*, and its other extremity is attached to the centre of a stretched membrane, *a*. A cone, *A*, is used to converge sound-vibrations upon the membrane. When a sound is uttered in the cone the membrane *a* is set in vibration, the armature *c* is forced to partake of the motion, and thus electrical undulations are created upon the circuit *E b e f g*.”

Having reference to the language used by you, particularly the words, “When a sound is uttered in the cone the membrane *a* is set in vibration,” I will ask you whether the function performed by the membrane of the lovers’ telephone or telegraph is the same as the function performed by the membrane *a*, illustrated in Fig. 7 of your patent?

Ans. No. In the lovers’ telephone or telegraph the two membranes are mechanically connected together by means of a stretched string. The function of one membrane is to pull the other, through the intermediary of the string. The membrane *a*, shown in Fig. 7 of my patent No. 174,465, is mechanically connected

— not with the other membrane, but with the armature *c* of the electro-magnet *b*; and the function of the membrane *a* is to cause the armature *c* to copy the form of the aerial vibrations produced by the voice when uttering a sound into the cone *A*, so that electrical undulations should be produced upon the circuit *E b e f g*, similar in form to the air-vibrations caused by the sound. In other words, the function of the membrane *a* is to create electrical undulations similar in form to air-vibrations caused by sounds. This is an entirely different function from that of the membrane of the lovers' telephone or telegraph.

Cross-Int. 310. Having reference again to Fig. 7 of your patent: If the membrane of the transmitter *a* is connected by a stretched string with the membrane of the receiver *i*, and the battery taken from the circuit, would the apparatus operate as a lovers' telephone or telegraph?

Ans. I presume you mean to remove not only the battery, but the electro-magnets *b f*, and armatures *c h*, and line wire *e* and ground connections *E g*; that is, I presume you remove the whole electrical part of the apparatus shown in Fig. 7, and have alone the cone *A*, with membrane *a*, and the hearing tube *L*, and membrane *i*; and you ask whether, if the membrane *a* was connected by a stretched string with the membrane *i*, the apparatus would operate as the lovers' telephone or telegraph. Practically, for the purpose of transmitting articulate speech to distant places, it would not operate. If the two membranes were not separated by more than a few hundred feet, it would operate like a lovers' telephone or telegraph; but, as in this case, it would not be an electrical arrangement; sound vibrations being mechanically conducted from the one membrane to the other along the string, the limit of its operation is soon reached. It certainly would not operate to transmit speech to any such distances as those intended in the case of the electric speaking telephones shown in Fig. 7, and the mode of operation would be entirely different.

Cross-Int. 311. My question was intended just as it was put. I did not intend that any change should be made in Fig. 7, except the removal of the battery from the circuit. This would leave the membrane *a* weighted, as I understand, to some extent, by the hinged

armature *c*, and the membrane *i* weighted, to some extent, by the hinged armature *h*, as I understand it, and a stretched string connecting the two diaphragms.

Ans. This does not materially affect the character of my reply. Under such circumstances — that is, with a stretched string connecting the two diaphragms, all the other arrangements shown in Fig. 7 of my patent No. 174,465, being retained, except the battery — speech would not be mechanically transmitted from the one diaphragm to the other through the string when the instruments are at any such distances apart as intended in the drawing, Fig. 7. You have, however, supposed in your question that the electrical arrangements shown in Fig. 7 also remained, with the exception of the battery. Practically, therefore, on account of residual magnetism, the electrical part of the apparatus would work. The vibration of the armature *c* carried by the membrane *a* would occasion electrical undulations upon the circuit *E b e f g*, similar in form to the air-vibrations caused by the sound uttered into the cone *A*. This undulatory current, passing through the electro-magnet *f*, would influence its armature *h* to copy the motion of the armature *c*, and a similar sound to that uttered into *A* would then be heard to proceed from *L*. Thus, upon the supposition that the transmitting and receiving instruments are doubly connected together (1) by means of the electrical arrangements shown in Fig. 7, but without any battery, and (2) by means of a stretched string connecting the membranes *a* and *i*; then, when the transmitting and receiving instruments are in different places at considerable distance apart, sounds would be heard from *L* similar to those uttered into *A*, by virtue of the electrical arrangements shown in Fig. 7, and not through the agency of the stretched string. Omit the electro-magnetic arrangements, or break the circuit *E b e f g* so as to leave the connecting string alone, and sounds would not be heard from *L* similar to those uttered into *A*, when the instruments are at any considerable distance apart. When they are only separated by feet instead of miles, sound vibrations would be transmitted from the one membrane to the other along the string, as in case of the lovers' telegraph or telephone; but I doubt whether this effect could be produced practically at even such a short distance as one mile, and

certainly for the distances intended to be shown in Fig. 7 it would not operate at all in that way.

Cross-Int. 312. My last question had no reference whatever to the distance at which the instruments were placed apart, and I conclude from your answer that, under the conditions stated in my questions, an apparatus constructed in accordance with Fig. 7 would transmit speech as the lovers' telephone transmits speech, when the battery is removed from the circuit, and the diaphragms are connected by a stretched string. My conclusion is correct; is it?

Ans. It is not correct if it has no reference whatever to the distance at which the instruments are placed apart; for the successful operation of the thread telegraph or telephone depends very materially upon the distance. If you limit your question to extremely short distances — so short as to constitute only small fractions of a mile — then I admit that under the conditions stated, speech would be mechanically transmitted from the transmitter to the receiver through the string, in the same manner as speech is transmitted in the lovers' telegraph or telephone. But speech would also be transmitted electrically from the transmitter to the receiver by means of the electrical arrangements shown in Fig. 7. As you increase the distance between the transmitter and the receiver, the mechanical transmission through the string will become feebler and feebler; whereas, the electrical transmission through the arrangements shown in Fig. 7 will not be materially affected at distances where the mechanical plan fails altogether to transmit.

Cross-Int. 313. One of the limitations of my question was that the instruments should be connected by a stretched string, and I intended to imply that they should be placed at the distance apart which is usual when the lovers' telephone or telegraph is used. I will put the question in a somewhat modified form. Referring again to Fig. 7: If the battery is removed from the circuit, and the armature *c* of the transmitting instrument A is connected by a stretched wire or string with the armature *h* of the receiving instrument L, and the instruments are placed at the distance apart which is usual when a lovers' telephone or telegraph is used, would the apparatus transmit sound or speech as a lovers' telephone or telegraph would transmit sound or speech?

Ans. If the instruments are placed apart at the distance that is usual where the lovers' telegraph or telephone is used, then the stretched string would transmit speech after the manner of the lovers telegraph or telephone, and the apparatus shown in Fig. 7 would also transmit speech electrically, after the manner of an electric speaking telephone. If, on the other hand, the instruments should be placed apart at the distance that is usual where electric speaking telephones are employed, the apparatus shown in Fig. 7 would practically transmit speech, and the stretched string would not. That is, under such circumstances, speech would be transmitted electrically by the apparatus shown in Fig. 7, and not mechanically through the stretched string.

Cross-Int. 314. You take the ground, do you, that the apparatus shown in Fig. 7 would work, even if the battery is removed from the circuit? Is that so?

Ans. Yes.

Cross-Int. 315. In taking this ground, and in your remarks about the residual magnetism of the electro-magnets, in your preceding answer, have you assumed that the ironwork of these magnets is made in the usual workmanlike manner — that is, for instance, that the magnets consisted of the best soft Swedish iron?

Ans. Yes. Though, theoretically, soft iron should have no residual magnetism, yet practically you always have a certain amount of residual magnetism in every magnet, though it may be made in the best way possible, and of the softest iron. But even were it possible to use in such an apparatus as that shown in Fig. 7 an electro-magnet with a core of iron such as described in your question, still the fact that the armature *c* is of steel would of itself necessitate residual magnetism in the arrangement when the battery is removed; and I know from experience that substantially similar apparatus to that shown in Fig. 7 does practically work without a battery upon the circuit.

Cross-Int. 316. Is it anywhere stated in your description of Fig. 7 in your patent No. 174,465 that the armature *c* is constructed of steel?

Ans. Yes. It is so stated. In the specification I say:

“In illustration of the method of creating electrical undulations, I

shall show and describe one form of apparatus for producing the effect. I prefer to employ for this purpose an electro-magnet, A, Fig. 5, having a coil upon only one of its legs *b*. A steel-spring armature, *c*, is firmly clamped by one extremity to the uncovered leg *d* of the magnet, and its free end is allowed to project above the pole of the covered leg."

In another part of the specification I describe the method of arranging the armature so as to enable motion to be imparted to it by the human voice, or by means of a musical instrument. In this part of the specification I say :

"One of the ways in which the armature *c*, Fig. 5, may be set in vibration has been stated above to be by wind. Another mode is shown in Fig. 7, whereby motion can be imparted to the armature by the human voice or by means of a musical instrument."

Cross-Int. 317. If I understand your answer correctly, you mean that the armature *c*, shown in Fig. 7, is precisely the same in all respects as the armature *c* in Figs. 5 and 6, except that in Figs. 5 and 6 the armature is so clamped as to have a spring movement, whereas in Fig. 7 it is not so clamped. Am I correct?

Ans. I would prefer to say that the armature *c*, shown in Fig. 7, is similar to the armature *c*, shown in Figs. 5 and 6, excepting that :

"The armature *c*, Fig. 7, is fastened loosely by one extremity to the uncovered leg *d* of the electro-magnet *b*, and its other extremity is attached to the centre of a stretched membrane, *a*."

This is the description of the difference given in the patent itself.

Cross-Int. 318. Is the function, office, or mode of operation performed by the transmitting membrane of the lovers' telephone or telegraph in receiving the vibrations of the air and imparting vibrations to the string, the same as the function, office, or mode of operation performed by the diaphragm *a*, of the transmitting instrument A in receiving the vibrations of the air and transmitting vibrations to the armature *c*? You will observe that this question has no relation to the electrical apparatus employed, but is simply intended to relate to the combination of the diaphragm *a* and the armature *c*, shown in Fig. 7.

Ans. I think the mode of operation of the membrane in the two cases stated is substantially similar. In the one case, the vibrations

of the membrane are mechanically imparted to the string, and in the other case they are mechanically imparted to the armature *c*.

Cross-Int. 319. Is the function, office, or mode of operation performed by the receiving membrane of the lovers' telephone or telegraph in receiving the vibrations of the string and imparting vibrations to the air, the same as the function, office, or mode of operation performed by the diaphragm *i* of the receiving instrument *L* in receiving the vibrations of the armature *h* and transmitting the vibrations to the air? You will observe that this question has no relation to the electrical apparatus employed, but is simply intended to relate to the combination of the diaphragm *i* and the armature *h*, shown in Fig. 7.

Ans. I think that the mode of operation of the receiving membrane is substantially the same in the two cases. In the case of the lovers' telegraph, the receiving membrane is pulled by the string. In the case of the arrangement shown in Fig. 7, the receiving membrane *i* is pulled by the armature *h*, and thus set in vibration.

Cross-Int. 320. In your answer to Cross-interrogatory 299 you say: "I do not know that I ever heard of the transmission of speech by Sir Charles Wheatstone." I suppose that answer refers to the period before you came to this country, does it not?

Ans. Yes.

Cross-Int. 321. As a matter of fact, Sir Charles Wheatstone did refer to the transmission of speech in connection with his apparatus, did he not?

Ans. So I am informed; but I do not think that I heard such a statement made until long after the issuance of my two patents No. 174,465 and No. 186,787, and not until quite recent years. I have not read anything of what Sir Charles Wheatstone himself has said upon this subject until last night, so far as I remember, when I saw what purported to be a copy from some paper by him. I always had the idea that Wheatstone's experiments related to a musical performance transmitted through a wooden rod; and while of course it was obvious to me that sounds of any sort could be transmitted in that same way, I certainly did not know that Wheatstone had actually transmitted speech in this way, or proposed to do so, until within quite recent years.

Cross-Int. 322. In your answer to Cross-interrogatory 306 you say that you are not sure whether you ever did yourself personally experiment with tin cans and a string. I gather from your mode of expression that although you did not yourself personally experiment with tin cans and a string, you witnessed or knew of such experiments. Am I correct?

Ans. Oh, yes. I have heard of such experiments and knew, of course, that the thing would work. I may have made the experiment myself, but I am not sure, and cannot recall any details when asked for a date.

Cross-Int. 323. You say, in answer to Interrogatory 41, that Professor Cross gave you your first information concerning the Reis telephone. A witness has been sworn in this case who states that his name is Charles R. Cross; age, 43; residence, Boston; occupation, teacher, Professor of Physics in Massachusetts Institute of Technology. Is he the Professor Cross to whom you refer in your answer to Interrogatory 41?

Ans. He is.

Cross-Int. 324. On October 5, 1891, Professor Charles R. Cross testified in this cause as follows:

"Q. 14. When did you first become acquainted with the instrument known as the 'lovers' telephone'?"

A. My first acquaintance with the instrument to which I suppose you refer was, if I remember rightly, in the fall of 1875, when they were exhibited and sold on the streets of Boston. I assume that you mean the little instrument with tin cylinders, membrane diaphragms, and a tight string connecting them. I was, of course, acquainted with various experiments of this character, like those of Wheatstone, prior to this date."

Were you in the habit of seeing much of Professor Cross during the years 1875 and 1876?

Ans. I saw him occasionally.

Cross-Int. 325. You were not able to fix very definitely yesterday the exact date when you first saw the lovers' telephone or telegraph. Does the fact that Professor Cross mentions the fall of 1875 as the time when they were exhibited and sold on the streets of Boston, enable you to fix this date more definitely?

Ans. No. His testimony does not help me there, because it was

certainly at a very much later date than the fall of 1875 that I saw the thread telephones for the first time. I was living at Exeter Place at the time, and Mr. Watson had then become my assistant. I did not live in Exeter Place until 1876, and my recollection is that our agreement with Mr. Watson was made on the 11th of September, 1876; and it was certainly not until about that time or later that I saw the lovers' telegraph exhibited for sale in the streets of Boston. I may say that since giving my testimony yesterday, I have refreshed my memory upon the matter, and can now assert positively that I saw the thread telegraph for the first time either on the 11th or 12th of September, 1876.

Cross-Int. 326. When did you first see a transmitting or a receiving instrument of a telephone which was provided with a metal diaphragm? In using the word "telephone," I use it in what I consider a generic sense, and intend it to apply to such circuit-breaking instruments as that of Helmholtz, the apparatus of Reis — or, indeed, any instrument capable of transmitting or receiving sounds.

Ans. In using the words "metallic diaphragm," I presume you mean a diaphragm capable of being set in vibration by the voice, or by sounds made in its neighborhood, and do not include under that head flat plates of metal like tuned reeds adapted to vibrate substantially at only one rate. I presume you mean a diaphragm that will vibrate at all rates, and copy the form of any vibration. With this understanding of your question, I may say that I first saw such a diaphragm used in my own telephones made in 1876. I invented it myself.

Cross-Int. 327. Professor Charles R. Cross testified in this cause, on October 5, 1891, as follows:

"Q. 17. When did you first take part in any experiments relating to the telephone? I use the word 'telephone' in its generic sense.

[*Standing objection.*]

A. I do not remember exactly, but think that it must have been about 1869 or 1870, certainly not subsequent to the latter date. I connected a tuning-fork transmitter with a receiver similar to that used by Reis, with some slight modifications of my own, and produced thus, at the farther end of the line, a note having the same pitch as that of the tuning-fork transmitter.

Q. 18. Still using the word 'telephone' in its generic sense, when and where did you describe such an instrument in your lectures?

[*Standing objection.*]

A. I cannot say positively when I first described this instrument. I think, however, that it must have been about 1870, when I began to lecture to the classes in Physics at the Institute. I described it in the course of my lectures on Acoustics, and also exhibited it.

Q. 19. What instrument is it that you described and exhibited in 1870?

[*Standing objection.*]

A. I described the Reis telephone. I exhibited a receiver which was substantially a Reis receiver used in connection with a circuit-breaking tuning-fork transmitter. The receiver differed from that of Reis in being larger and in having several wires passed through the magnet-coil of the apparatus, instead of only one. I did not possess a Reis transmitter.

Q. 20. When did you next exhibit and use a telephone in your lectures after the lecture of 1870, to which you referred in your last answer?

[*Standing objection.*]

A. I cannot say certainly, but I was in the habit of describing the apparatus to my classes, and frequently exhibited it each year when I took up the subject of Acoustics.

Q. 21. Did you use in your experiments and lectures, after 1870, the same telephone that you have described in your last two preceding answers, or did you use one of changed construction?

[*Standing objection.*]

A. I did both.

Q. 22. Please describe the telephone of changed construction, and when it was first used?

[*Standing objection.*]

A. I showed a receiver of different form for the first time publicly in February, 1872, at a public lecture. The new element in the apparatus was a receiver which was of a form that had been used in some experiments by Professor Pickering several years before in connection with an imperfect kind of circuit-breaking transmitter. The receiver exhibited at the date referred to consisted of a large plate of tinned iron which constituted the bottom or one side of a packing case in which some instruments had been imported. The case was rectangular in form, $38\frac{1}{2}$ inches long, $21\frac{1}{2}$ inches broad, and 19 inches deep. As shown in the lecture, the box was placed upon its side, so that the bottom of the box was in a vertical position. The box was secured to the table on which it rested so that it should be firm. Opposite the centre of the great diaphragm, formed by the bottom of this box, was placed an electro-magnet, whose legs were about six inches long, and whose cores were something over one inch in diameter. This magnet was fixed upon a support so that its poles were quite close to the plate, but not in contact with it, even when a current of electricity was caused to flow through the coils of the magnet. On the opposite side of the room from this receiver

was placed a circuit-breaking tuning-fork, that is, a tuning-fork furnished with a metallic stile which dipped into a cup of mercury and was connected in circuit with a battery and the receiving apparatus so that the current should be made and broken when the fork vibrated, once for each vibration of the fork. A battery of six Grove cells, if I remember rightly, was placed in circuit with the tuning-fork transmitter and the receiver, a line wire running across the room and connecting the two. As I remember it, the particular tuning-fork used made 128 vibrations per second, so that when it was vibrating, the circuit was broken 128 times in each second. The tuning-fork was set in vibration by striking it with the hand or with some other soft object, and was allowed to vibrate until it came to rest. Whenever the circuit at the tuning-fork was closed, a current of electricity flowed through the circuit, including the coils of the electro-magnet, and in consequence of the attraction of this electro-magnet, the diaphragm was pulled towards the poles of the magnet. On the other hand, whenever, on account of the vibration of the fork, the stile attached to it was lifted out of contact with the mercury in the cup below it, the circuit was broken, the electro-magnet became demagnetized, and the pull on the diaphragm being released and thus under the influence of its own elasticity, the diaphragm moved away from the poles of the magnet. Since the tuning-fork made and broke the circuit 128 times per second the diaphragm was pulled and released the same number of times per second and hence executed 128 vibrations per second. Under these circumstances sound-waves corresponding to this frequency of vibration were produced in the air so that a note of a pitch corresponding to this rate of vibration was heard to issue from the receiver. This note of course corresponded in pitch with the note given by the tuning-fork transmitter, since this fork executed the same number of vibrations per second, which rate of vibration, as always, determined the pitch.

Q. 23. Of what material was the diaphragm of the receiving apparatus described in your last answer composed?

[*Standing objection.*]

A. It was the ordinary tinned iron of commerce.

Q. 24. When was the next experiment or use that you made of this receiving apparatus described in your last answer?

[*Standing objection.*]

A. The next time that I remember using it was about two years later. In the latter part of December, 1873, or early in January, 1874, I employed the same receiver in some experiments, but substituted for the tuning-fork previously employed, an automatic Helmholtz's tuning-fork interrupter which the Institute had recently purchased. This instrument was so constructed that it kept up its vibration indefinitely. I tried a number of experiments with this apparatus, using tuning-forks of several different rates. Shortly after this

I again exhibited the apparatus at a public lecture at the Institute of Technology, which was given early in January, 1874. In this lecture I employed but one of the several tuning-forks which I had previously experimented with as transmitters.

Q. 28. What caused you to prepare the receiving apparatus which you used in 1872, 1873 and 1874?

[*Standing objection.*]

A. I was lecturing on Acoustics and used the apparatus especially in illustrating the fact that vibrations of any kind, however produced, give rise to sound-waves. The Reis telephone and the apparatus under consideration exhibited some unusual modes of producing vibrations, and hence I thought it would be of interest to my audience to witness their operation.

Q. 29. Is the apparatus which you have described and which you used at your lectures, in existence at the present time; if it is, where is it?

[*Standing objection.*]

A. It is; that is, all the essential parts of it,—the transmitters, the electro-magnet, and the large tin box. They are all of them at the Institute in our collection of apparatus.

Q. 30. Will you sell or give them to complainant, so that they may be made exhibits in this case?

[*Standing objection.*]

A. Personally I have not such control of the apparatus as to allow me to do this. I do not think that the Institute would desire to part with them.

Q. 31. Will you please offer a diagram fully illustrating the construction of the apparatus which you used in your experiments of 1872?

A. I will, and hereby produce it.

[*Witness produces the diagram hereto annexed.*]

Q. 32. Please also indicate the parts of the apparatus by suitable letters.

[*Standing objection.*]

A. In the diagram which I have produced, F is the tuning-fork transmitter, B is the battery, M is the electro-magnet, and D is the diaphragm formed by the bottom of the box which is represented in the figure as resting upon its side.

[*The diagram referred to by the witness in his last answer is offered in evidence by the complainant, and marked "Exhibit Cross Apparatus, H. L. H., Examiner."*]

[*Standing objection.*]

Q. 52. You spoke yesterday of your acquaintance with Professor Alexander Graham Bell; was Professor Bell a student at the Massa-

Massachusetts Institute of Technology or an attendant upon lectures there at any time when you were a student or instructor at that institution?

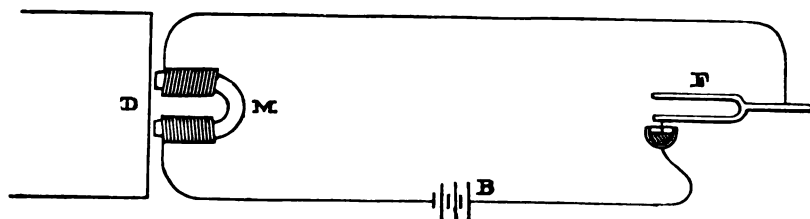


Exhibit Cross Apparatus, H. L. H., Examiner.

A. Professor Bell never attended any course of lectures given to students at the Institute. He was present at a portion of a course of Lowell Lectures, so called, given by me at the Institute to a miscellaneous audience of outside persons in the winter of 1873 and 1874.

Q. 53. Did Professor Bell at the time that he attended the Lowell Lectures, or at any other time, see any electrical apparatus belonging to you or to the Massachusetts Institute of Technology?

A. He did.

Q. 54. Please state, as nearly as you recollect, what electrical apparatus Professor Bell saw.

A. It is impossible for me to say with any definiteness just what he did or did not see of electrical apparatus, as he was at the Institute frequently, and probably saw a good many different pieces. He gave much more attention, so far as time was concerned, to acoustic apparatus than to electrical apparatus.

Q. 55. Please state whether or not the receiving apparatus used by you at the Massachusetts Institute of Technology in 1872, 1873, and 1874, as you have testified, was among the acoustic instruments in which Professor Bell was interested.

A. I have no reason to suppose that Mr. Bell ever saw this instrument in operation, for although I exhibited it in this course of lectures, I am not aware that he was present at that particular one, and have reason for supposing that he was not present at that particular one. According to the best of my recollection, I described this apparatus, together with the apparatus of Reis, to Mr. Bell at some time in the early winter of 1874 or in the spring of that year. I do not recollect that he was particularly interested in it, nor do I recollect anything beyond the fact that I did describe it to him.

Q. 56. Have you any recollection whatever of what Professor Bell said, when you described the receiving apparatus to him?

A. Not the least.

Q. 57. Have you had any conversation with Professor Bell about that tin box receiving apparatus since you exhibited it to him as testified?

A. I do not remember distinctly with regard to this. I have an impression that we have conversed on the subject, but at the same time will not be positive.

Q. 58. Did this conversation of which you have an impression occur prior to, say, March, 1876?

A. No. Any such conversation occurred subsequently to this, and I think subsequently to 1879."

Have you any reason to doubt the accuracy or truthfulness of Professor Cross's statements?

Ans. I should not think of doubting the general accuracy and truthfulness of any statements that Professor Cross might make; but at the same time, I believe him to be as liable to error as any other truthful man. If he has stated in his testimony that he ever showed me any such apparatus as that illustrated in the diagram contained in his answer to Question 32 of his deposition, and described in that answer, he is mistaken. It seems to be assumed in Question 57 that he has so stated; but I do not find any definite statement to that effect from Professor Cross himself, although in answer to Question 55 he says he thinks he *described* the apparatus to me. I may say that I have no recollection of any such description, and certainly never saw the apparatus illustrated in the diagram contained in his answer to Question 32. What I did see at the Institute of Technology was a very different apparatus, which purported to be the receiving instrument of Reis's telephone. It consisted of a single straight coil with a straight iron core, or cores, inside. I did not see it in operation. Professor Cross — so far as I remember — pointed it out to me upon a shelf. My recollection is that the coil was very much longer and larger than the receiving instrument of the Reis telephone I afterwards saw at the Smithsonian Institution in Washington.

Professor Cross, in his answer to Question 55, speaks of having described the apparatus of Reis to me "at some time in the early winter of 1874 or in the spring of that year." I have reason to believe, as I have stated in answer to Interrogatory 41 of the present deposition, that the apparatus of Reis was not shown or described to me until after November 26, 1874. If Professor Cross asserted positively that he had described it to me before that date, I should of course believe him; but, so far as I can judge from his deposi-

tion, his recollection of the date is vague, and based upon memory alone; whereas my recollection of the date has been refreshed by a contemporaneous record—a letter written to Mr. Gardiner G. Hubbard on the 26th of November, 1874. In that letter I described experiments that show that on November 26, 1874, I discovered substantially the Reis receiver, and thought it original with myself. My recollection, as refreshed by this letter, is that I showed my experiments to Professor Cross, very shortly after the 26th of November, 1874, and that he then told me that what I had discovered was not new; that it was substantially the Reis receiver over again. And my recollection is further that he invited me to go and see the apparatus at the Institute of Technology. I remember that I did so, and he pointed to a long coil of wire containing an iron core, or cores, upon a shelf, and told me that was the Reis receiver, but I did not see it in operation.

Cross-Int. 328. In your answer to Question 73 you refer to a letter to Mr. Hubbard, dated Salem, Mass., June 28, 1875. The letter contains the statement:

“Professor Pickering has left town for the summer. I propose having the steel reed still further altered tomorrow,” etc.

I fail to gather from the letter what bearing the fact that Professor Pickering had left town for the summer had upon the subject-matter thereof, and should be glad if you would explain.

Ans. At that time I knew Professor Pickering, and was not acquainted with Professor Lovering, although perhaps I might have met him before June 28, 1875, though I do not think I had. The steel reed referred to had been vibrated by wind in front of an electro-magnet, and had been operated as a transmitter without any battery upon the circuit. It had produced from a tuned-reed receiver in the circuit a very perceptible musical sound. I recognized that the vibration of the steel reed had occasioned a magneto-electric current, and I felt sure, as I stated in this letter, that a study of Ladd's or Wilde's magneto-electric machine would reveal a means of increasing the intensity of the induced currents. Professor Pickering at this time was, I think, Professor of Physics in the Institute of Technology. Knowing him, I naturally desired to get information from him concerning the construction of Ladd's and

Wilde's magneto-electric machine. Finding, however, that he had left for the summer, I called upon Professor Lovering of Harvard College, and sought the information from him.

Cross-Int. 329. A witness has been duly sworn in this case, who says his name is Edward C. Pickering; age, 45; residence, Cambridge; occupation, astronomer, director of Harvard College Observatory. Is he the person to whom you refer as Professor Pickering, in the letter to which I called your attention in my last preceding question?

Ans. He is.

Cross-Int. 330. On the 26th of October, 1891, Professor Edward C. Pickering testified in this cause as follows:

"Q. 5. Are you acquainted with Professor Alexander Graham Bell?

A. I am.

Q. 6. Were you acquainted with him during the period that you were employed in the Massachusetts Institute of Technology between February 1867 and February 1877?

A. I was during the last portion of the time.

Q. 7. What, if any, connection did Professor Bell have with the Massachusetts Institute of Technology between February 1867 and February 1877?

A. Professor Bell desired to make some investigations on the transmission of sound electrically, and I offered him what facilities we could in the laboratory of the Institute."

Do the facts thus testified to by Professor Edward C. Pickering agree with your recollection?

Ans. They agree with my recollection, so far that the professors of the Institute of Technology always extended to me the greatest courtesy, and placed all their apparatus at my disposal for any experiments I desired to make. So far as I remember, however, the investigations I desired to make at the Institute of Technology, and did make, had reference, mainly, to the use of the manometric capsule and the phonautograph of Léon Scott, as improved by Mr. Morey of the Institute of Technology. It may be possible that I made investigations there on the transmission of sound electrically, but I do not recollect any experiments of that kind made at the Institute, excepting as illustrations to public addresses or lectures given there by me.

Cross-Int. 331. To what extent did you avail yourself of the facilities offered by Professor Pickering, and other professors of the Institute of Technology?

Ans. I went there and made a large number of experiments with the phonautograph, obtaining tracings of speech sounds upon smoked glass. I also borrowed the manometric capsule, and took it home with me. I remember, also, borrowing the manometric capsule, the phonautograph, and a large model of the human ear, together with, I think, models of the larynx and vocal organs, for the purpose of exhibiting them publicly at the Convention of Articulation-Teachers of the Deaf and Dumb, which met in the city of Worcester, Mass., on the thirteenth day of June, 1874. This is the meeting I referred to in my answer to Interrogatory 31. I do not remember making any electrical experiments at all at the Institute of Technology, excepting, as I say, in connection with my public lectures. I remember examining with care the vowel apparatus of Helmholtz, and requesting information concerning it from the professors, either Professor Pickering or Professor Cross. I remember expressing a desire to see it operated, and remember my disappointment when I was told that they had not been able to obtain, at the Institute, the effects stated by Helmholtz. In general, I availed myself of the facilities of the Institute, chiefly by calling there occasionally and getting information from Professor Pickering or Professor Cross on scientific matters. I do not mean to assert positively that I may not have made electrical experiments there relating to the transmission of sound, but I do not remember having done so.

Cross-Int. 332. When did you first become acquainted with Professor Pickering, and when did you first know Professor Cross?

Ans. I think it was in the winter of 1873-74 — though, now I think of it, I am inclined to believe I knew both of them, or had met both of them while I lived at West Newton Street, which would make it the winter of 1872-73. I certainly knew them both in the spring or early summer of 1874, when I was making experiments with the phonautograph. If I had met them before that time, I had simply met them casually. But I was at the Institute so often during the early summer of 1874, on account of phonautographic experiments, that I then came to know them both pretty well.

Cross-Int. 333. Were you present at the Lowell lectures given at the Institute of Technology in the winter of 1873-74?

Ans. No. I did not attend these lectures. I was present, however, at one of these lectures, or at least during a portion of the lecture. I heard that a lecture was to be given, I think upon Helmholtz's researches, and that the vowel apparatus of Helmholtz was going to be shown, and I think, therefore, made an effort to attend that lecture, and was there during a portion of the time at least; and spoke to Professor Cross after the lecture, and examined the apparatus. I am not at all sure but that was the first time I met Professor Cross, but I cannot pretend to know the particular date.

Cross-Int. 334. Did Professor Cross deliver the lecture referred to in your last answer?

Ans. I am not sure. It was given either by Professor Cross or Professor Pickering. At that time, if I remember rightly, Professor Cross was Professor Pickering's assistant. Professor Cross, however, was present, and it may be possible that he was the lecturer; but I cannot remember now.

Cross-Int. 335. Was this apparatus of Helmholtz's, referred to by you in your last answer, the one described in his work, which I believe consists in a circuit-breaking tuning-fork arranged in the same circuit with a number of other tuning-forks and other appliances?

Ans. Yes. The apparatus itself is shown in Fig. 18 of my London lecture,* which is in evidence in this case.

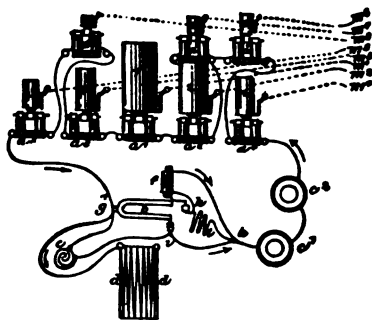


Fig. 18.*

Cross-Int. 336. Was any other apparatus of Professor Cross or Professor Pickering on exhibition at that time?

Ans. I do not remember. It was the Helmholtz apparatus that I was specially interested in, and that is the only apparatus I remember seeing on that occasion.

Cross-Int. 337. Professor Cross has, I believe, referred in his testimony to the fact that he used at a lecture a circuit-breaking tuning-fork of Helmholtz in connection with what he terms a tin-box receiver. I gather from what you say that this tin-box receiver did not form a part of the apparatus on exhibition at the time you attended the lecture referred to by you. Am I correct?

Ans. I feel quite sure it did not, or I certainly would have remembered it. In referring to this lecture, I may say that I have assumed it to be one of the course of Lowell Lectures, but really, so far as I know, I am not entitled to assert this. I simply know it was a lecture given at the Institute of Technology, by either Professor Pickering or Professor Cross, during the course of which the Helmholtz apparatus was shown and described. In regard to its date, now I come to think of it, I am pretty sure that I was residing at the time in West Newton Street, Boston; and not in Salem. I resided at West Newton Street from October 1, 1872, up to the summer of 1873. If the Lowell course referred to was in the winter of 1873-74, I feel sure that it was not one of those lectures at all that I attended, for my recollection is very distinct that I was residing at West Newton Street at the time. Another reason that confirms this date in my mind is that I learned of the fact that the Helmholtz apparatus was going to be shown from Miss Abby A. Locke, who was my assistant at West Newton Street, and the teacher directly in charge of my little pupil, George Sanders, at that boarding place. I rather think she had attended some lectures at the Institute, and had thus learned that the Helmholtz apparatus was going to be shown. After my return from Canada, about the first of October, 1873, I resided in Salem, and taught my little pupil there myself, at the house of his grandmother.

Cross-Int. 338. A part of the testimony of Professor Cross, to which I called your attention this morning, was as follows:

"Q. 56. Have you any recollection whatever of what Professor Bell said when you described the receiving apparatus to him?

A. Not the least.

Q. 57. Have you had any conversation with Professor Bell about that tin-box receiving apparatus since you exhibited it to him as testified?

A. I do not remember distinctly with regard to this. I have an impression that we have conversed on the subject, but at the same time will not be positive.

Q. 58. Did this conversation of which you have an impression occur prior to — say March, 1876?

A. No. Any such conversation occurred subsequently to this, and I think subsequently to 1879."

Are you able to fix the date of the conversation referred to in the testimony just quoted?

Ans. In regard to the receiving apparatus referred to in Question 56, which I understand to mean the Reis receiver; Professor Cross described and showed to me that apparatus shortly after the 26th of November, 1874. In regard to the tin-box receiving apparatus referred to in Question 57, I am quite certain that I knew nothing about it until the matter came up in some telephone lawsuit, about the year 1879. If I held any conversation with Professor Cross upon the subject, it was after that date. If any such conversation occurred, I cannot now recall the details of it.

Cross-Int. 339. In Question 55 of Professor Cross's deposition, the interrogator uses the following language :

"Please state whether or not the receiving apparatus used by you at the Massachusetts Institute of Technology in 1872, 1873 and 1874, as you have testified, was among the acoustic instruments in which Professor Bell was interested."

And in the next succeeding question, 56, the interrogator uses the following language :

"Have you any recollection whatever of what Professor Bell said when you described the receiving apparatus to him?"

In using the words "receiving apparatus" in these two questions, do you understand that the interrogator had reference to the Reis receiver, or to what has been termed by Professor Cross the tin-box receiving apparatus?

Ans. I do not know exactly what the interrogator meant by the term. It seemed to me that the expression "receiving apparatus" was rather vague. That is why I desired to give it a definite mean-

ing in my last preceding answer. I observe that in Professor Cross's answer to Question 55 he uses this language :

" According to the best of my recollection, I described this apparatus together with the apparatus of Reis to Mr. Bell," etc.,

as if there were two receiving apparatuses. Then, in Question 56, the interrogator asks when Professor Cross described the " receiving apparatus " to me ; whereas, in the succeeding question, 57, the interrogator inquires about " the tin-box receiving apparatus." I therefore assumed that Question 56 referred to the Reis apparatus, and Question 57 to the tin-box apparatus. I simply wished to be definite in my statements and to state clearly my understanding of the question.

Cross-Int. 340. Please state all that you knew about the tin-box receiving apparatus in 1879?

Ans. I knew nothing more, I think, excepting that the statement had been made that such an apparatus had been used at some early date at the Institute of Technology, in connection with some circuit-breaking device.

Cross-Int. 341. What law-suit is it that you refer to in connection with the tin-box receiver?

Ans. I do not know. It might, perhaps, have been the *Dowd* suit, but I cannot be certain. I mention the year 1879 because there were no telephone law-suits before that year. I do not mean to assert positively that the law-suit I refer to occurred in that year. I mean simply to say that I learned of the fact subsequently to the commencement of litigation concerning telephone matters.

Cross-Int. 342. Perhaps I may be able to assist your memory by a quotation from Professor Cross's deposition. Professor Cross testified as follows :

"Q. 45. At whose request did you make these experiments in 1879 with the Blake transmitter and the tin-box receiver?

[*Standing objection.*]

A. At the request of Mr. Chauncey Smith and Mr. James J. Storrow.

Q. 46. For what purpose were the experiments of 1879 made?

[*Standing objection.*]

A. They were made in order to show that the receiver which I had used with a circuit-breaking apparatus, was capable, if put in

circuit with a suitable speaking-telephone transmitter, of reproducing the quality of the voice or other sounds.

Q. 47. Why was it thought desirable or necessary to establish the fact mentioned in your last answer?

[*Standing objection.*]

A. I do not know. I do not remember that I distinctly understood this at the time. From what I have learned subsequently, I judge that the experiments were tried in consequence of the relations of this instrument and its operation, to certain devices which Mr. Elisha Gray had described, and which had been put forth as speaking-telephone receivers. My own experiments, as I understand, antedated the apparatus of Mr. Gray, which apparatus, like my own, had been employed only in connection with circuit-breaking apparatus. My own apparatus was capable of doing everything which any apparatus described by Mr. Gray was capable of doing; and from this I have inferred that my experiments showed Mr. Gray's apparatus to have been anticipated, and hence of no particular importance in relation to speaking-telephone receivers, even admitting all claims put forward as to the date of its construction, and all arguments based on its mode of operation. This supposition, however, so far as I can recall, is a matter of my inference, and not a matter regarding which I was particularly instructed at the time of the experiments. All that I remember understanding with regard to the matter at the time, was that my apparatus was earlier than Mr. Gray's, and that it was desired to know whether mine would or would not do all that it was alleged Mr. Gray's apparatus did.

Q. 48. Why was it desirable to ascertain or know that your apparatus anticipated that of Gray?

[*Standing objection.*]

A. I do not remember that I was ever informed beyond what I have already stated.

Q. 49. Please state whether or not the experiments made by you in 1879, of which you have testified, were made by you with a view to testifying concerning them in any suit?

[*Standing objection.*]

A. They were; and shortly afterwards I gave a deposition regarding them.

Q. 50. What deposition was this to which you refer in your last answer; in what suit was it given?

[*Standing objection.*]

A. I do not recall the precise title of the suit. We called it *The Harmonic Telegraph* suit.

Q. 51. In a suit formerly pending in the Circuit Court of the United States for the District of Massachusetts, No. 1134, Equity, entitled 'The Harmonic Telegraph Company *et al.* v. The New England Telephone Company,' the bill of complaint, filed February 3, 1879, contains the following allegations among others."

Was this suit, No. 1134, Equity, entitled *The Harmonic Telegraph Company et al. v. The New England Telephone Company*, the suit to which you have referred in connection with the tin-box receiving instrument?

Ans. I am sure I don't know. My information about the matter was simply hearsay information, picked up in conversation with some of our counsel. I do not think I ever saw any of the testimony about the matter; and what you have just read I learned for the first time to-day, so far as I can remember.

Cross-Int. 343. You say in answer to Question 331, that you availed yourself of the facilities of the Institute of Technology chiefly by calling there occasionally, and getting information from Professor Pickering and Professor Cross on scientific matters. Please make this portion of your answer a little more definite by stating exactly what you meant by the words "scientific matters."

Ans. I referred more particularly to matters relating to physics, and specially subjects relating to Helmholtz's researches, and other researches relating to phonautographs and such apparatus. These were the special subjects upon which we conversed. As I was at that period of time imperfectly acquainted with electricity and magnetism, I frequently took the opportunity of requesting from them titles of papers or books upon these subjects, which I afterwards studied.

Cross-Int. 344. Professor Cross also testified in this cause as follows:

"Q. 146. You have spoken of conversations with Professor Bell. Do you remember among these conversations any statements, either by Mr. Bell or yourself, in relation to the Reis telephone prior to the year 1876?

A. Not very definitely. I recollect explaining the operation of the Reis telephone to him at some time prior to 1876.

Q. 147. Do you remember how long prior to 1876 this was?

A. I have an impression that I spoke to him about the Reis telephone in the spring of 1874. I remember again, a good while after that, I should say over a year later, that he showed me an apparatus which he thought would surprise me, and seemed to have rediscovered the Page effect, which is utilized in the Reis telephone. I at that time, when the apparatus was first shown me, spoke again of the telephone of Reis. Mr. Bell seemed to have forgotten the operation of a receiver like that of Reis."

Professor Cross, in this testimony, seems to refer to two different occasions upon which he conversed with you about the Reis instrument. So far, you seem to have been able to recollect but one of these occasions. Having thus heard the testimony of Professor Cross, will you state what your present recollection is upon the subject?

Ans. Professor Cross's recollection seems to be more definite than mine. I do not mean to deny that he may have spoken to me about the Reis telephone in the spring of 1874; but I do not recollect the circumstance, and it is obvious from my letter of November 26, 1874, to Mr. Hubbard, that if such conversation actually took place, it had not made an impression upon my mind. The second conversation to which Professor Cross refers, I presume is the one that I remember; if so, he is mistaken in supposing that it was over a year later than the spring of 1874, for my recollection is very positive that it took place very shortly after the 26th of November, 1874 — probably within a day or two after. I remember that such a conversation took place, from the fact that he told me that my discovery of November 26, 1874, was not original with myself, but was utilized in the Reis receiver. I may say that my own unaided memory does not warrant me in saying that it was Professor Cross who told me this. I simply remember that one of the professors of the Institute of Technology informed me of the fact, and I presume, from having seen extracts from Professor Cross's evidence, that Professor Cross was my informant. If it had not been for this evidence, I should have supposed my informant to have been Professor Pickering.

I observe that on the twentieth day of February, 1877, Professor Cross testified concerning this subject in the *Harmonic Telephone Interferences*. Referring to the autumn of 1874, and to the experiments made in Kilby Street, which are described in my letter to Mr. Hubbard, of November 26, 1874, Professor Cross, testifying on the twentieth day of February, 1877, said:

“Late in the autumn of that same year, if I recollect rightly, I called upon Mr. Bell at his workshop, and witnessed the transmission of sounds by means of a peculiar receiver constructed of a steel spring. He showed me several other instruments for the same purpose at the same time. At that time Mr. D. B. Hagar, principal of

the State Normal School at Salem, was also present. A receiving instrument was also used, embodying the principle used in Reis's telephone, which principle, as I understood Professor Bell, he had rediscovered, he not being at that time familiar with Reis's experiments. These devices used intermittent currents.

The pieces of apparatus which I have referred to as having seen at the office in Kilby Street, in the presence of Mr. Hagar, are represented in Figs. 18 and 23 of Preliminary Statement." *

In the experiment illustrated by Fig. 23 of my preliminary statement in the *Harmonic Telegraph Interferences*, the receiving instrument consisted of a straight coil of insulated wire containing two cylindrical cores of iron with an iron nail between them, the three pieces of metal lying loosely in the coil. In my letter to Mr. Hubbard of November 26, 1874, referring to the place where the experiments were made, I said :

"Mr. Blake (father of Dr. Clarence J. Blake) having kindly offered me the use of a room in his building, No. 77 Kilby Street, Boston, I, this morning, proceeded to set up there the apparatus constructed for me by Mr. Hamilton (Mr. Farmer's assistant)."

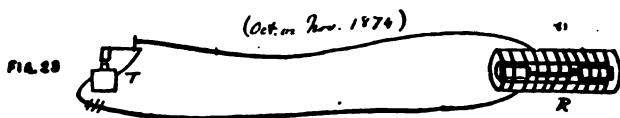
Cross Int. 345. Professor Cross has also testified in this cause as follows :

"Q. 188. Did you describe the Helmholtz apparatus to Mr. Bell at the same time that you described the Reis apparatus to him, or at any time prior to 1876?

A. No. Indeed, I had no need to do so; Mr. Bell was perfectly well acquainted with the Helmholtz apparatus when I first met him in the winter of 1873 and 1874."

Is this testimony of Professor Cross in accordance with your recollection?

Ans. I was perfectly well acquainted with the drawings of the



apparatus and with the acoustical principle involved, but I cannot say that I understand fully, even today, all the electrical details of these drawings. I never saw the apparatus before it was shown to me at the Institute of Technology. At that time I understood perfectly the acoustical part.

Cross-Int. 346. I have understood you to say substantially, in a previous answer, that your unaided recollection would have prompted you to say that it was Professor Pickering who had the conversation with you about the Reis instrument. Why Professor Pickering?

Ans. Because it was Professor Pickering, if I mistake not, who was Professor of Physics at the Institute of Technology at that time, and not Professor Cross. Professor Cross, I think, was his assistant, I do not doubt, however, for one moment, that it was Professor Cross who had the conversation, for he so testifies.

Cross-Int. 347. Professor Cross has also testified in this cause, as follows :

“ Q. 210. Cross-question 93, and your answer thereto, is as follows :

‘ Did he, at or about that time, and during the fall and winter of 1874–1875, state to you anything concerning the structure of the instrument which he proposed to employ in the transmission of speech upon this plan?

A. He did, if my memory serves me correctly. I understood that he proposed to cause an armature of some kind, made of iron, to be vibrated under the action of the voice, to and fro, opposite the pole of an electro-magnet, and thus to produce electrical undulations in the circuit of which that electro-magnet formed a part.’

Have you ever given that description before in any cause?

A. I have done so. This was in the *Baxter Overland* case, so called, one of the various cases which was considered by the Supreme Court.

Q. 211. Did Mr. Bell make this statement to you, which you have referred to in your last two answers, before or after you described to him the tin-box receiving apparatus?

A. A good while after, according to the best of my recollection.

Q. 212. Was this statement of Mr. Bell's brought about or caused by your description to him of the tin-box receiving apparatus, or talk between you and him about the tin-box receiving apparatus?

A. It was not.

Q. 213. What did give rise to the conversation, if you recollect?

A. I don't remember. I suppose Mr. Bell was describing some of his ideas to me, as he had not infrequently done before.”

Does this testimony of Professor Cross agree with your recollection?

Ans. I remember that I did, sometime in the autumn of 1874, describe to one of the professors of the Institute of Technology — I presume Professor Cross — the structure of the instrument which I proposed to employ in the electrical transmission of speech, and that the instrument I described to him was substantially similar to the apparatus, Fig. 7, of my patent of March 7, 1876, No. 174,465. I rather think, however, that at that time I proposed to operate it without a battery. In regard to what gave rise to the conversation, I cannot be perfectly certain, but am inclined to think that the conversation originated from the experiments of November 26, 1874. I am inclined to think that the description given to me, shortly after that date, of the musical telephone of Reis, led me to tell Professor Cross about my ideas concerning the transmission of articulate speech.

In regard to the tin-box receiving apparatus — I have no recollection of the conversation with him upon the subject referred to, and I feel perfectly certain that Professor Cross is mistaken upon this matter; for if any such conversation had taken place, I certainly would have remembered it for the following reason: Professor Cross says in his answer to Question 55:

“According to the best of my recollection, I described this apparatus, together with the apparatus of Reis, to Mr. Bell at some time in the early winter of 1874, or in the spring of that year.”

Now, in the year 1874, it was not a new fact to me that a flat plate of iron used as the armature of an electro-magnet, in connection with a circuit-breaking device, could be forced by a powerful intermittent current to produce a musical tone of different pitch from that which by its structure it was normally fitted to produce. It was not a new fact to me that such a plate could be forced to reproduce the pitch of the circuit-breaker employed to interrupt the voltaic current, whatever that pitch might be. It was not even a new fact to me that the forced vibrations of such a plate under the influence of a powerful intermittent current from two circuit-breaking devices of different pitch would produce in the listener's ear, from that one plate, a sensation of two musical tones — the unisons

respectively of the circuit-breaking devices employed to interrupt the voltaic current. These facts I discovered myself in November, 1873. In my present deposition, in answer to Interrogatory 23, I described the experiments referred to, and stated that they were made during the winter of 1873-74. In my testimony in the *Dowd* suit, in answer to Interrogatory 19, I described the same experiments and gave a definite date — November, 1873. If, then, Professor Cross had told me, in 1874, of similar effects produced at the Institute of Technology, I certainly would have remembered the circumstance, on account of my own discoveries of the year previous.

Cross-Int. 348. Did you ever, at any time up to the present moment, use the tin-box receiver referred to by Professor Cross in his testimony, and illustrated in his answer to Question 32?

Ans. No.

Cross-Int. 349. Did you ever, at any time up to the present moment, use an instrument exactly like it?

Ans. As I have not, to my knowledge, seen the instrument referred to, I cannot say. I did use a flat plate of steel clamped at one end, and damped by pressure against my ear, in connection with a circuit-breaking device, in November 1873.

Cross-Int. 350. This flat plate of steel which you used in connection with a circuit-breaking device did not differ at all in its operation from the tuning-forks used by Helmholtz as a receiver, did it? For instance, suppose you had taken the apparatus of Helmholtz as illustrated in his work and referred to by you, and placed your ear against the receiving tuning-fork; would not you have obtained the same result as with the flat bar to which you refer?

Ans. In regard to the first part of the question — the flat plate of steel, when used in the way I have described, did, I think, differ materially from the tuning-fork receivers employed by Helmholtz. On account of the extended flat surface, the plate of steel when pressed against my ear became, to all intents and purposes, a metallic diaphragm in contact with the ear. When the ear was not in contact with the plate of steel, it had a tendency to vibrate at a definite rate of its own, and in this respect it resembled the tuning-fork receiver of Helmholtz, but when it was damped by pressure against the ear, the free vibration of the plate was prevented, so that its mode of

operation was then entirely different from the tuning-fork receiver of Helmholtz.

In regard to the second part of the question — the experiment has never been made, to my knowledge. If it had been made at the date of my experiments — November, 1873 — and had resulted in success, it would, I think, have been a new discovery ; but, in the supposed case, the tuning-fork, not having an extended flat surface like the steel plate, would not, when damped against the ear, have constituted a metallic diaphragm in contact with the ear.

Cross-Int. 351. I should be glad if you would explain why Helmholtz's tuning-fork would not produce the same effect as one of your flat bars, to which you refer. In asking for this explanation, I will presume in the experiment to which you have referred, that a Helmholtz tuning-fork is substituted for the flat bar, all other parts remaining constant.

Ans. I have not stated that Helmholtz's tuning-fork would not produce the same effect ; but that the experiment has never been tried, to my knowledge. What I did say, in substance, was, that even if the same effect should be produced (which, of course, is all speculation, as the experiment has never been tried) ; the tuning-fork, having too slight an extent of surface, and too great a depth or thickness, would not, like the flat plate I employed in November, 1873, when pressed against the ear, constitute a metallic diaphragm applied to the ear.

Cross-Int. 352. Are you able to give me some idea of the difference, in extent of surface, between the upper side of one of Helmholtz's largest tuning-fork receivers and the upper side of the plate that you used in your experiments?

Ans. I do not know the size of the tuning-forks employed by Helmholtz, but it is obvious from the usual relations of the parts of a tuning-fork that the larger the extent of surface of the upper side of one of Helmholtz's tuning-forks, the greater would be the thickness of the prong ; the relation between surface and thickness being, I suppose, about the same as in the ordinary tuning-forks we are all familiar with. I should think that the upper side of the flat plate used in my experiments, in November, 1873, had a length of about six inches, by a width of about one inch, and I should think the

plate was about one thirty-second of an inch thick. I cannot pretend to be precise, but I think these dimensions convey a pretty good idea of the character of the plate employed.

Cross-Int. 353. As I gather from your direct examination that you have experimented somewhat extensively on the thickness of diaphragms, I will ask you how thick may the diaphragm of a receiving telephone be, and yet transmit to the ear speech which may be understood?

Ans. There is a relation between the thickness and diameter of a diaphragm suitable for use in an electric speaking telephone. This relation has been arrived at empirically by numerous experiments. The relation is found in the diaphragms of electric speaking telephones now in use. If you take diaphragms of ordinary diameter, but thicker than those now in use, you will find that each increase of thickness interferes with the intelligibility of the articulation by changing the character or quality of the voice. With very thick diaphragms of ordinary diameter, a sort of Punch-and-Judy effect is produced of a very disagreeable character. Again, using diaphragms of usual diameter but thinner, the intelligibility of the speech is again affected; a curious, hollow sound tinges the articulation; and with very thin diaphragms, the effect produced is as though one spoke with his head inside a barrel or cave. Again, suppose you use diaphragms of similar thickness to those now in use, but of different diameters. The Punch-and-Judy effect is gradually produced by diminishing the diameter, and the hollow and resonant effect by increasing it. Just how far the thickness of a diaphragm may be increased without destroying intelligibility, I am not prepared to say; but every departure from the ratio between diameter and thickness established in the commercial instrument, interferes with the articulation, and produces an injurious effect.

Cross-Int. 354. I find the following statement in Prescott's book about the telephone, referred to by you in your direct examination:

"In the experiments which Mr. Bell has carried out in order to determine the influence of the various parts of the telephone on the results produced, and their relations to each other when the best effects are obtained, he employed iron plates of various areas and thicknesses, from boiler plate three-eighths of an inch in thickness, to the thinnest plate procurable. Wonderful to relate, it appears that

scarcely any plate is too thin or too thick for the purpose, but the best thickness is that of the ferrotype plate used by photographers. Thin tin plate also answers very well."

I find a foot-note at the bottom of the page of the chapter of the book in which this language is contained, which seems to indicate that it is taken from the *Westminster Review*, although I do not pretend to be certain about this. Please state whether or not that statement was authorized by you.

Ans. I do not know the authority for the statement, but it is substantially correct. Following the last sentence you have quoted, that "Thin tin plate also answers very well," it is stated that: "The iron plate is cut into the form of a disk about two inches in diameter," etc. Ferrotype iron and thin tin of that diameter answer very well. With thicker plates the diameter had to be increased to obtain the best effects, and with thinner plates it was best to diminish the diameter. Very great ranges of both diameter and thickness, however, could be made without destroying the intelligibility of the speech, though every change affected the character or quality of the articulation.

Cross-Int. 355. Is anything said in your patents No. 174,465 and No. 186,787, about the length, breadth or thickness of the diaphragms, or is any instruction given in either of those patents as to the dimensions of the diaphragms?

Ans. In these patents I had no intention of limiting myself to diaphragms of particular length, breadth, and thickness, as I knew these might be varied within wide limits; and I believed that instruments constructed from the specifications and drawings of these patents, by persons skilled in the arts to which they refer, would operate to transmit articulate speech. In relation to patent No. 174,465, I presumed that membranes of such diameter and thickness as were usually employed in the construction of phonautographs and apparatus of that description would do. In regard to patent No. 186,787, I presumed that any competent workman would understand that the mouth-piece at the end of the tube E, in Fig. 1, was intended to cover the mouth, and was therefore intended to be about the size of the usual mouth-piece employed in speaking-tubes and apparatus of that sort. Upon this understanding he would

obtain from the drawings in Figs. 2 and 3 a sufficiently definite idea of the diameter and thickness of the metal diaphragms, to be enabled to construct, without any further description than is given in the specification itself, a practically operative electric speaking telephone.

Cross-Int. 356. I gather from your last answer that the diaphragm marked A, in Fig. 2 of your patent No. 186,787, was intended to be in height and width about three times the diameter of an ordinary house speaking-tube. Is my conclusion justly made from your testimony?

Ans. I do not mean to say that I intended to limit the size or area. I do not mean to say, therefore, that the metallic diaphragm marked A, in Fig. 2, must necessarily be of the size specified in your question. I only mean to say that if it was constructed of that size it would work.

Cross-Int. 357. I will put the question in a somewhat modified form. If Fig. 2 had been constructed to a scale, the unit of measure of which had been a distance equal to the diameter of the cylindrical part of an ordinary house speaking-tube, the diaphragm A would have been in height about three units of this measure, and in breadth about three units of this measure. Would it not?

Ans. I think about that. I have not measured the drawing, but I should think it would be probably less than that. To my eye it appears about three times the diameter of the tube E, and would therefore be less than three times the diameter of the mouth-piece.

Cross-Int. 358. In the course of your acoustical investigations, have you ever had occasion to ascertain the usual diameter of the cylindrical part of an ordinary house speaking-tube?

Ans. I do not know that I have actually measured it. I only have the same general recollection that we all have of the usual size of such tubes.

Cross-Int. 359. Have you ever, up to the present moment, used the ordinary tin of commerce as a diaphragm for a telephone transmitter or a telephone receiver?

Ans. Yes. I have used the ordinary tinned iron of commerce, to which I presume you refer.

Cross-Int. 360. When was it, as nearly as you recollect, when

you first used the ordinary tinned iron of commerce, either as a diaphragm for a transmitter or receiver? In answering this question you need not limit yourself to electrical telephones.

Ans. I am sure I don't know. It never occurred to me to distinguish tinned iron from iron that was not tinned, and I cannot now distinguish experiments made with the tinned iron of commerce from experiments made with untinned sheets of iron; for of course such experiments happened a great number of years ago.

Cross-Int. 361. From the fact that it never occurred to you to distinguish whether the iron was tinned or not, I conclude that it makes no difference in using telephone diaphragms whether the iron is tinned or not. Am I correct?

Ans. I do not think it makes much difference.

Cross-Int. 362. Does it make any difference at all?

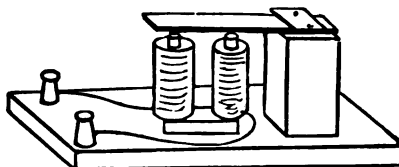
Ans. I am sure I don't know.

Cross-Int. 363. You say in answer to Cross-interrogatory 352, that you think that the outside of the flat plate used in your experiments of November, 1873, had a length of about six inches, by a width of about one inch, and that this plate was about one thirty-second of an inch thick. Is that plate shown in any drawings that you have referred to on your direct examination? In this question I include the drawings forming part of your preliminary statement in the *Harmonic Telegraph Interferences*.

Ans. Such plates are shown in Figs. 5 and 7 of the drawings of my preliminary statement in the *Harmonic Telegraph Interferences*, and the mode of mounting the plate in the form of apparatus which was pressed to the ear, in my experiments made in November, 1873, is described in my present deposition in answer to Interrogatory 22. I described this apparatus and pictured it in the *Dowd* case, in answer to Interrogatory 18, where I said:

"I now make a drawing of my favorite form of receiving instrument in November, 1873."

I here insert a copy of the drawing thus referred to.



Cross-Int. 364. Your preliminary statement in the *Harmonic Telegraph Interferences* is dated Boston University, April 27, 1876; and the oath forming a part thereof is dated May 15, 1876. Was that preliminary statement prepared between its date April 27, 1876, and the date on which it was sworn to, May 15, 1876?

Ans. I judge entirely of the time of preparation by the date upon the document itself. I presume, therefore, that it was prepared on or before April 27, 1876, and sworn to May 15, 1876. I have no recollection of the date except from the document.

Cross-Int. 365. Do you remember how long after the formal declaration of the *Harmonic Interferences* you commenced the preparation of the preliminary statement which has been put in evidence?

Ans. The *Harmonic Telegraph Interferences* were formally declared, as respects my application of February 25, 1875, on February 16, 1876. My preliminary statement was signed at the Boston University April 27, 1876, and sworn to May 15, 1876.

Cross-Int. 366. The date, Boston University, April 27, 1876, then, I suppose, indicates the time when the preliminary statement was finished, does it?

Ans. I presume so, but I have no other source of information than the document itself. I do not remember anything about it independently of that.

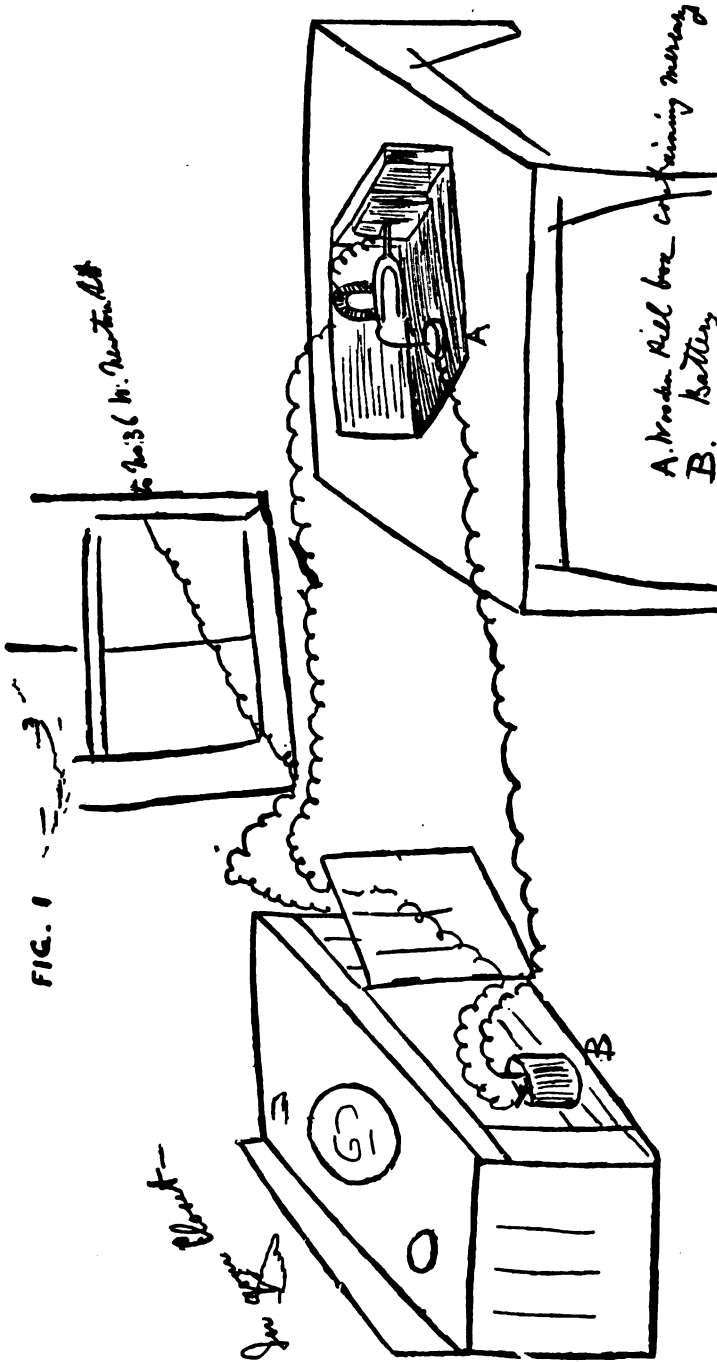
Cross-Int. 367. In this preliminary statement in the *Harmonic Interferences* you say:

"The experiments undertaken in Boston during the winter of 1872-73 related more particularly to the mechanical means of transmitting vibrations. I was acquainted with Helmholtz's apparatus for the artificial production of vowel sounds, and all my earlier experiments were modelled upon his. Figs. 1 and 2 illustrate the first form of apparatus constructed in West Newton Street."

From your statement, and an inspection of these figures, I conclude that the apparatus illustrated in Figs. 1 and 2 and 3* was precisely the same in its mode of operation as the apparatus of Helmholtz, except, perhaps, that one receiving tuning-fork was used instead of two or more; am I correct?

Ans. It was not precisely the same. It differed materially in the fact that a telegraph key was employed, by the manipulation of which

* For Figs. 1, 2 and 3 see pages 247 and 248.

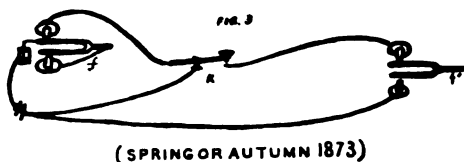
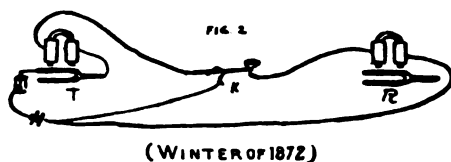


Apparatus constructed by A. Graham Bell during the winter of 1872-3.
 Drawn from memory (Feb. 1876) by P. S. Richardson (a witness of the
 experiment).

the receiving apparatus could be caused to emit long or short musical signals, like the dots and dashes of the Morse alphabet. Otherwise than this, I should think that the mode of operation was substantially similar to that of the Helmholtz apparatus, though differing considerably in detail.

Cross-Int. 368. Any Helmholtz apparatus—as, for instance, the one illustrated in your London lecture*—may be used as a harmonic telegraph for transmitting the signals of the Morse alphabet, by simply making and breaking the circuit after the usual manner of telegraphers; may it not?

Ans. Perhaps so, but I don't know. I do not sufficiently understand the operation of the transmitting part of the apparatus to be able to decide this. It may be that the opening of the circuit would cause the transmitting fork to stop vibrating, and that it would not be set into vibration by the closure of the circuit, without being mechanically started in vibration. As I do not fully understand the electrical arrangements connected with the transmitting fork, I cannot decide the point. Helmholtz does not seem to have provided any means of making and breaking the circuit in the manner supposed. I used a telegraph key, and that was a necessary part of my invention.



* See page 230 *supra*.

Cross-Int. 369. Does the apparatus illustrated in Fig. 3 differ in any way from the Helmholtz apparatus except in the introduction of a key into the circuit? The object of this question is that I may understand more clearly your statement in the *Harmonic Interferences*, in which you say :

"I was acquainted with Helmholtz's apparatus for the artificial production of vowel sounds, and all my earlier experiments were modelled upon his."

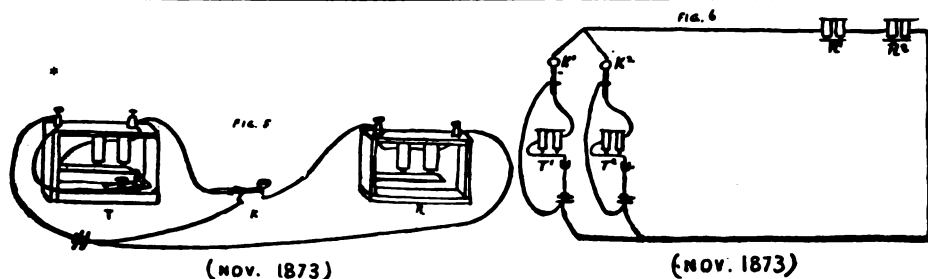
• I will say that I use the word "Helmholtz apparatus" in its generic sense, meaning it to apply to the circuit in which is a circuit-breaking tuning-fork as a transmitter, and one or more tuning-forks as receiver or receivers.

Ans. There are numerous differences in the details of construction and in the mode of connection in circuit; but I think that when the key K, in Fig. 3 of my preliminary statement in the *Harmonic Telegraph Interferences* is depressed so as to have the transmitter and the receiver in the same voltaic circuit, there is substantial similarity in the mode of operation.

Cross-Int. 370. You also say in the preliminary statement in the *Harmonic Interferences* :

"Somewhere about November, 1873, an article entitled 'The Acoustic Telegraph,' published in 'The Wonders of Electricity,' led me to substitute steel plates for tuning-forks in my telegraphic experiments. Two transmitting instruments and two receiving instruments (specimens of which are still in my possession in their original form) were made like those shown in Fig. 5.* These were arranged on circuit, as shown in Fig. 6."*

Will you be kind enough to state what it was in the article entitled "The Acoustic Telegraph" which led you to substitute steel plates for tuning-forks?

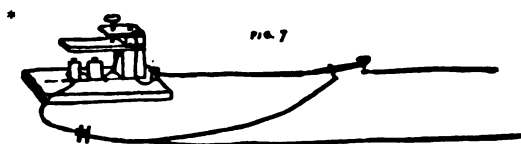


Ans. The article referred to on "The Acoustic Telegraph" was contained in a volume entitled *Wonders of Electricity*, translated from the French of J. Baile, published in New York, 1872, pages 140-43. An original copy of this book is now before me. The same article on "The Acoustic Telegraph" is No. 53 of the so-called Reis publications, which I understand to be in evidence in this case. The exact part of the article that led me to substitute steel plates for tuning-forks was a passage which reads as follows :

"A vibrating plate produces a sound, and, according to the rapidity of the vibrations, these sounds are sharp or flat. At each of the vibrations the plate touches a small point placed in front of it, and this contact suffices to throw the current into the line; when the plate ceases to vibrate and returns to its position of equilibrium, it no longer touches the metal point, and the current is consequently interrupted. By this means is obtained a series of interruptions, more or less rapid, according to the sound, the current being thrown into the line and interrupted once for each of the vibrations.

At the extremity of the line the current enters an electro-magnet which attracts another vibrating plate of size and quality identical with the former. Attracted and repelled very rapidly, exactly, and as rapidly, in fact, as the plate mentioned above, this second plate gives forth a sound which will have the same musical value as that of the other, as the number of vibrations per second is the same in both cases."

It was the perusal of the passage quoted above that led me to substitute steel plates for tuning-forks. One form of apparatus, constructed in November, 1873, upon the suggestion of this passage, is shown in Fig. 5 of my preliminary statement in the *Harmonic Telegraph Interferences*. Fig. 7* shows a transmitter, which was also constructed about the same time, in which the plate made and broke contact with a metallic point. Instruments of similar construction to these, Fig. 7, but without the metallic point, were also used as receivers in November, 1873. I have given a drawing of such a receiving instrument in my answer to Cross-interrogatory 363.



(WINTER OF 1873)

Cross-Int. 371. Does the apparatus illustrated in Fig. 5 of your preliminary statement, in the *Harmonic Telegraph Interferences*, differ in any way from the apparatus the description of which you have just given?

Ans. Yes. It differs from it in the fact that a telegraph key is employed, by the manipulation of which the receiver can be caused to emit long or short musical signals corresponding to the dots and dashes of the Morse alphabet. The transmitting instrument also is of different construction from that mentioned in the passage.

Cross-Int. 372. The transmitting instrument shown in Fig. 5 differs, if I understand you correctly, from the transmitting instrument described in the article, in that Helmholtz's circuit-breaking contrivance is used, such as you have before described. Is that so?

Ans. No. A plate is employed, and not a tuning-fork, but the plate in vibrating causes a vertical wire to make and break contact with mercury, as in the Helmholtz apparatus.

Cross-Int. 373. Such circuit-breaking devices as you have described in your last answer were in common use among physicists even before the apparatus of Helmholtz had been published to the world. Were they not?

Ans. I am sure I don't know.

Cross-Int. 374. Continuing the article from the "Wonders of Electricity" from where you left off, the following language is used :

"Should this process be perfected, it will be possible to transmit sound by means of the telegraph, to transmit a series of sounds, a tune, or spoken sentence and conversation. This consummation has not, however, been yet attained. Many experiments have been made, the principle has been applied in divers ways, and everything makes us hope that we will yet arrive at a perfect system of acoustic telegraphy. Advances have been made very far upon the road to success. A series of vibrating plates answering to the strings of a harp has been arranged, each of which vibrates when struck by a particular sound, and sends off electricity to create at the end of the line the same vibrations in a corresponding plate, or, in other words, to produce the same sound."

Does the apparatus described in Fig. 6 of your preliminary statement in the *Harmonic Interferences* differ from the apparatus described in the paragraph I have just read?

Ans. I think it does differ very materially. No mention or suggestion is made of the very object of the arrangement in Fig. 6,* viz. : the simultaneous transmission along a single wire of two or more distinct telegraphic messages without interference with one another. Nor is any mention or suggestion made of certain of the instrumentalities shown in Fig. 6, which formed an integral part of my invention. I allude to the combination with the transmitting instruments of telegraph keys whereby the transmitters could be connected with the line wire, as desired, and long and short musical signals be made, corresponding to the dots and dashes of the Morse code.

Cross-Int. 375. When the words "a series of vibrating plates" are used in the paragraph quoted by me, do you understand that the same vibrating plates are referred to, which are described in the paragraph quoted by you?

Ans. I don't know.

Cross-Int. 376. In applying the information contained in the article in the "Wonders of Electricity" to your experiments, did you understand to what particular apparatus the article referred?

Ans. No. I did not.

Cross-Int. 377. I notice from a letter of the Examiner contained in the records of the file-wrapper and contents of your application filed February 25, 1875, that a description in the *Comptes Rendus*, 1860, Vol. 50, p. 692, is referred to; also, English patent No. 1775 of 1863. Was the apparatus referred to by the Examiner, the same as that referred to in the "Wonders of Electricity"?

Ans. I cannot tell. I do not know precisely what apparatus was referred to in the article in the "Wonders of Electricity," but am inclined to think it was the apparatus of M. L'Abbé Laborde. From my lecture of May 10, 1876, before the American Academy of Arts and Sciences, I find that Laborde's experiments are published in the *Comptes Rendus*, Vol. 50, p. 692, and also in *Cosmos*, Vol. 17, p. 514. My knowledge of Laborde's researches was obtained very shortly before May 10, 1876.

Cross-Int. 378. Has a patent ever been granted to you based on your application of February 25, 1875, which has been offered in evidence?

* For Figure 6 see page 249.

Ans. My multiple-telegraph inventions were made the subject-matter of three separate applications, one filed February 25, 1875, another filed March 6, 1875, and the third filed March 10, 1875. The second of these issued as patent No. 161,739, dated April 6, 1875. This patent and the other two applications were involved in interference with Elisha Gray. All the points of interference were decided in my favor, but no patents have been granted on the applications of February 25, 1875, and March 10, 1875.

Cross-Int. 379. I understand from what you have said, and the documents referred to on your direct examination, that Helmholtz used a single circuit-breaking transmitter, and two or more tuned receivers of different pitch in his apparatus. Does the apparatus shown in Fig. 6 differ from Helmholtz's except in the use of two circuit-breaking transmitters? Of course I wish to be understood that each is provided with a battery.

Ans. Yes. The apparatus shown in Fig. 6 differs very materially from the apparatus of Helmholtz, quite independently of the fact that two transmitters are shown of different construction from Helmholtz's transmitters, each provided with a separate battery and a telegraph key. There is another very important and radical difference, upon which, indeed, depends the successful operation of the system of multiple-telegraphy illustrated by Fig. 6. It is that the pitches of the receiving instruments are so arranged, relatively to one another, that the electrical impulses transmitted from one of the transmitters will produce powerful vibration in one, and one only, of the receivers. In Helmholtz's apparatus all the receiving instruments, though of different pitch, responded to a single transmitter. In Helmholtz's apparatus the musical tones produced by the receivers were harmonics of that produced by the transmitting fork. In mine they were not.

Cross-Int. 380. In your answer to Cross-interrogatory 377 you referred to an apparatus of M. L'Abbé Laborde and to Laborde's experiments published in the *Comptes Rendus* and *Cosmos*. Will you please give either a brief or a full description, as you may prefer, of this apparatus of M. L'Abbé Laborde?

Ans. It is a great many years since I read the account of Laborde's experiments, and I do not now remember anything more

about them, excepting the fact that I was impressed by the idea that the passage from the "Wonders of Electricity," which I have quoted in answer to Cross-interrogatory 370, and which I had read a long time before, had reference to Laborde's experiments. If you desire further information, I shall be happy to look the article up at one of the libraries here, and refresh my recollection of Laborde's researches.

Cross-Int. 381. I gather from your answer to Cross-interrogatory 378 that you were acquainted with the apparatus of M. L'Abbé Laborde some time prior to May 10, 1876, and also prior to the preparation of your paper which was read before the American Academy of Arts and Sciences. Are you able at this time to state, either exactly or approximately, when it was that you first became acquainted with the apparatus of Laborde?

Ans. I am only able to state positively that in my paper of May 10, 1876, I gave in a foot-note a reference to Laborde's experiments. Whether I had actually read the article before that date, I do not know. All that I can say is that I found a reference to it, and so mentioned it in my paper. I intended in that paper to give the public all the information concerning the researches of others upon the subject of electric telephony that I myself possessed, and I gave reference to the writings of others, quite independently of the fact that in many cases I had not read the articles to which they referred. I may add that I was unable to read any of the German articles referred to in the original text. I cannot pretend to say now whether I read the article of Laborde before or after the tenth day of May, 1876; but if it was before, it was very shortly before that date, and while I was collecting references in the course of preparation for my paper read before the American Academy of Arts and Sciences.

Cross-Int. 382. Will you be kind enough to distinguish, if you are able to do so, the printed publications cited or referred to in your lecture before the American Academy, which you had consulted or read, from those printed publications which you had not consulted or read.

Ans. In my paper of May 10, 1876, I cited or referred to printed publications of the following persons: Page, Marrian, Beatson,

Gassiot, De la Rive, Matteucci, Guillemin, Wertheim, Wartmann, Janniar, Joule, Laborde, Legat, Reis, Poggendorff, Du Moncel, Delezenne, Ferguson, Elisha Gray, Paul La Cour, Helmholtz, Canon Goltoin de Coma, Gore, Sullivan, and Koenig. I also alluded to all the anonymous articles referring to electrical production of sound to which I had discovered references. I cannot now distinguish the articles that I read before May 10, 1876, from those that I read after. I was unable, as I have stated, to read the German articles in the original text; the French I had very little difficulty with. My recollection is that I had read very few of the articles referred to before the tenth day of May, 1876. Very shortly before that date, and in preparation of my paper, I began a search for articles relating to the production of sound by electrical means, and I remember that I was surprised at the number of references I was able to find. After the tenth day of May, 1876, I tried to find the articles themselves with which I was not acquainted, so as to study them. Later on, but at what date I cannot say with precision, I had translations made of many of the German articles, so that I could see what they referred to. I may add that at some period I have read, either in the original text or in the shape of a translation, nearly all the articles referred to in my lecture of May 10, 1876; but very many of them were not accessible to me till years after the issuance of my two patents No. 174,465 and No. 186,787.

Cross-Int. 383. Can you distinguish those printed publications which were accessible to you before the dates of your two patents, from those which you were not able to obtain until after the issue of the patents?

Ans. I cannot do so otherwise than by stating that as a general rule the articles in English or French were accessible to me, and the German were not.

Cross-Int. 384. You mean, do you, that as a general rule the articles in English and French were accessible to you before the dates of your two patents?

Ans. They were accessible, in the sense that I could read them and understand them. I think there were some cases, however, where I could not find the works referred to in the Boston libraries, and so had to hunt them up elsewhere at a later date than my patent

of January 30, 1877. I may say that previous to the issuance of my patent of March 7, 1876, I was very ignorant of the literature relating to the production of sound by electrical means.

Cross-Int. 385. I notice that you have been very particular to give the volume number, page number, and publication date of the works to which you have referred in your lecture before the American Academy. Did you obtain these volume and page numbers and dates from the original works in the libraries?

Ans. In very few cases. I think I obtained a very large number of them from *Kuhn's Encyclopædia der Physik*.

Cross-Int. 386. You have spoken of the procurement of German translations. Will you please be kind enough to designate those extracts which were translated for you, and as nearly as you can, when the translations were made?

Ans. I cannot say with precision. At some subsequent period after the issuance of my patent of January 30, 1877, I desired to make myself familiar with the literature on the subject of electric telephony. I had translations made of nearly all the foreign articles referred to in my paper of May 10, 1876 — at least the German articles — and manuscript copies made of the articles in the French and English languages. I cannot fix the date any more accurately than to say it was after January 30, 1877. Most of the translations I think were made after my marriage, July 11, 1877; and very many of them not until long after that date. I think that some of them were not made until 1879 or 1880.

Cross-Int. 387. Who made the earlier translations referred to in your last answer; and where were they made?

Ans. I am sure I cannot say at the present time who made the translations referred to. The translations were made at different times, and by different individuals. I made some of the translations from the French myself. In regard to the place, some of them were made in this country — in Boston and Washington — and some in England.

Cross-Int. 388. When did you first go abroad after coming to America, in 1870, as you have testified?

Ans. About the 4th of August, 1877.

Cross-Int. 389. That was the journey abroad, was it not, to which you referred on your direct examination?

Ans. Yes. The first journey abroad to the other side of the Atlantic. I don't suppose you allude to Canada as "abroad," in this connection.

Cross-Int. 390. Then I infer that the translations, to which you refer as having been made in Boston and Washington, were made prior to the 4th of August, 1877; were they?

Ans. Most of them were made after. It may be possible that some were made in Boston before that date, but I cannot be sure now. The ones made in Washington were certainly after.

Cross-Int. 391. In your lecture before the American Academy referred to, you spoke of Elisha Gray, and made the following reference in a foot-note:

"*Elisha Gray.* Eng. Pat. Spec., No. 974. See 'Engineer,' March 26, 1875."

When did you first become acquainted with this English patent of Elisha Gray referred to?

Ans. I do not know positively whether I ever became acquainted with the patent referred to. I am inclined to think from the foot-note in my paper of May 10, 1876, that I had seen some article from the "Engineer" of March 26, 1875, which alluded to the patent referred to. I may or may not have seen the patent specification itself; I am sure I cannot tell now.

Cross-Int. 392. In your lecture of May 10, 1876, before the American Academy, you also refer to Elisha Gray as follows:

"Elisha Gray has also produced audible effects by the passage of induced electricity through the human body."

And in a foot-note you say:

"*Elisha Gray.* Eng. Pat. Spec., No. 2646. See 'Engineer,' Aug. 14, 1874."

When did you first see this English patent of Elisha Gray's, No. 2646?

Ans. I am not sure whether I have seen the patent specification referred to at all. I presume from the foot-note alluded to that my information was derived from the "Engineer" of August 14, 1874. I

may say that in both this and the preceding case I feel quite certain that if I have seen the patent specifications referred to, it has been since May 10, 1876. I have no doubt whatever that the information I incorporated in my paper of May 10, 1876, was derived directly from the "Engineer."

Cross-Int. 393. Were you a subscriber for the "Engineer" during the years 1874 and 1875, or did you see it regularly during those years?

Ans. No. I have never been a subscriber for the "Engineer," and have never seen it regularly.

Cross-Int. 394. You have stated that Professor Cross called your attention to Reis. Did he call your attention to any printed publications relating to the Reis instruments?

Ans. I don't know, but think it very likely that he may have done so.

Cross-Int. 395. Do you remember when your attention was first called to the Reis publications by anyone?

Ans. I don't know that my attention was first directed to the Reis publications by anyone else than myself. It is very possible, however, — nay, probable, — that Professor Cross or Professor Pickering may have given me references to papers relating to the Reis telephone. If so, I do not remember the circumstance clearly, and I certainly discovered for myself references to Reis publications, when preparing my paper of May 10, 1876, and before that.

Cross-Int. 396. Among the printed publications referred to in your lecture of May 10, before the American Academy, will you please designate those which relate to Reis or his apparatus.

Ans. Those that specifically relate to Reis are given as follows: Under the head of *Reis*:

"Téléphonie." Polytechnic Journ., CLXVIII., p. 185; Böttger's Notizbl., 1863, No. 6";
and under the head of *Legat*, "Brix. Z. S., IX., p. 125."

I think a number of the articles under other names also contained references to Reis's experiments, but I cannot identify them at the present time from the references alone.

Cross-Int. 397. Under the head of *Poggendorf*, you refer to two

volumes of *Poggendorff's Annalen*. To what particular matter did you intend to refer in those volumes?

Ans. *Poggendorff's Annalen* is a scientific periodical. The Roman numerals refer to the number of the volume, and the Arabic numerals to the page. I cannot tell to what particular matter the references refer, without consulting the periodical itself. Before I wrote my paper of May 10, 1876, I had probably found some reference to these articles in *Poggendorff's Annalen*, showing that they had something to do with the production of sound by electrical means, and I therefore copied the references in my paper.

Cross-Int. 398. The bill of complaint in the equity suit entitled, *Harmonic Telegraph Co. et al. v. New England Telephone Co.*, which has been introduced in evidence in this case, alleges the infringement of certain letters patent originally granted to Elisha Gray on the twenty-seventh day of July, 1875, and afterwards reissued in two divisions on the twenty-eighth day of January, 1879; said divisions being numbered respectively 8558 and 8559. I have heretofore called your attention to this suit, and I will now ask you whether my reference to the patents of Gray refreshes your recollection to any extent concerning it.

Ans. No. I do not think that I ever knew anything personally about that suit. My patents and the companies organized under them have been involved in quite a number of suits of which I know nothing whatever, personally. So far as I can recollect, the suit referred to is one of those of which I am entirely ignorant. I would not even have known that such a suit had ever been brought, from my own memory or knowledge, but for the fact of your mentioning it. I am not conscious of having ever seen any of the evidence in the case, excepting so far as you may have brought it to my notice.

Cross-Int. 399. Do you know whether or not the United States letters patent of Gray, to which I have referred in my last question, covered the same subject-matter as the English patents of Gray to which you have referred in your lecture before the Academy of Arts, May 10, 1876?

Ans. No. I am sure I do not know.

Cross-Int. 400. Have you ever had occasion to investigate these

United States patents to Gray, to which my last two questions referred?

Ans. No; excepting so far as I may perhaps have read them. I have not made a study or investigation or close examination of any of the United States patents to Mr. Gray. I may have read them through; but I cannot say whether I have even read those particular patents to which you refer, without looking them over.

Cross-Int. 401. When was it that you first saw any printed publication relating to the Reis apparatus?

Ans. I cannot tell positively. I feel quite sure, however, in my own mind, that I knew nothing of Reis's experiments before the 26th of November, 1874. Very shortly after that date, I was told of the Reis musical telephone by Professor Cross, and it may be possible that he may have referred me to some printed publication at that time, but I don't know. I am inclined to think that my first reading of publications relating to Reis's researches was somewhere about the date of my paper before the American Academy, May 10, 1876.

Cross-Int. 402. When Professor Cross, described Reis to you, as stated in your last answer, did he make use of any illustrations, cuts, drawings, or printed matter of any kind?

Ans. I don't know. My recollection of the details of the conversation is very vague. I remember simply the fact that I was told that Reis had done substantially what I discovered on the 26th of November, 1874. That fact made an impression upon my memory. I remember also that the Reis receiver was pointed out to me at the Institute of Technology, on a shelf somewhere. I presume the Reis telephone and its mode of operation were described to me at the time, but I cannot distinguish now between the knowledge that was given to me upon that occasion, and the knowledge that I have subsequently acquired. I should be very glad to be more definite in my reply, but my memory of the details of the conversation is vague.

Cross-Int. 403. I wish you would refer to the volume containing the publications of Reis, to which you have referred, and select, if you can, an instrument similar to that which was shown to you at the Institute of Technology, as you have testified in your last answer.

Ans. I do not think that any of the drawings are similar to the instrument which was shown to me at the Institute of Technology. The receiving instrument shown in "No. 26, Reis's Circular of August, 1863," somewhat resembles it, but I do not think there was any sounding-box or telegraph-key attached to the instrument. About the 2d of March, 1875, I saw the apparatus represented in this drawing, both transmitter and receiver, at the Smithsonian Institution, in Washington. If I remember rightly, the coil of the receiver did not exceed six inches in length, but the coil of the receiver shown to me at the Institute of Technology very much exceeded this in dimensions.

Cross-Int. 404. The drawing of the Reis receiver to which you have just referred is substantially similar to that illustrated in Vol. 126 U. S. Reports, page 100, is it not?

Ans. I think it is substantially similar. The exact drawing, however, may be found on page 60 * of the same volume you have referred to.

Cross-Int. 405. Professor Cross has testified in this case as follows:

"Q. 148. Have you ever used a Reis receiver in circuit with a transmitter of any kind?

[*Objected to as immaterial and irrelevant to any issue raised by the pleadings in this cause.*]

A. I have used a Reis receiver in circuit with a microphone transmitter, the ordinary Blake transmitter, if I remember rightly.

Q. 149. Please give the results of that experiment.

[*Same objection.*]

A. I found myself able, with care, to reproduce articulate speech with a receiver connected up as described.

Q. 150. Please state whether or not you find a cut or description of the Reis receiver used by you in this experiment in Vol. 126 U. S. Reports.

[*Same objection.*]

A. There is a cut showing it on p. 100, the receiver is at the right of the cut." †

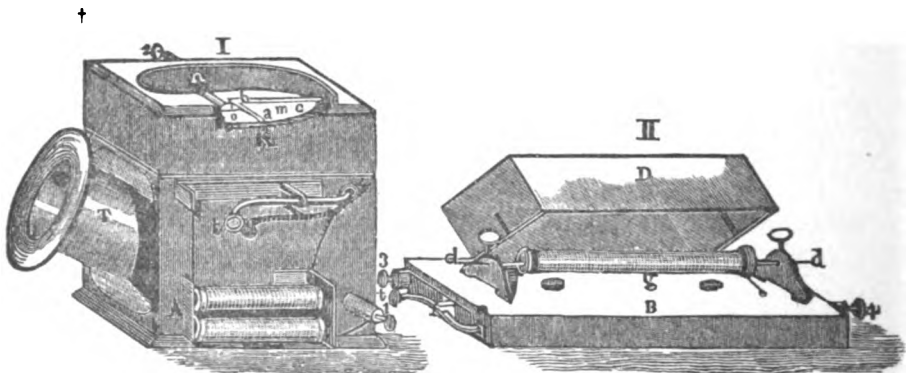
When, if ever, did Professor Cross call your attention to the fact that he had found himself able, with care, to reproduce articulate

*The cut referred to is shown on p. 51. *supra*.

† See page 262.

speech with a receiver similar to that illustrated on page 100 of Vol. 126 U. S. Reports, as stated by him in the testimony just quoted?

Ans. I do not remember ever having heard of the circumstance from Professor Cross himself. With the knowledge given by me to the world in my two patents No. 174,465, of March 7, 1876, and No. 186,787, of January 30, 1877, it is difficult to say what form of receiver will not talk when operated upon the method I have described and claimed in those patents. If the receiving instrument of Reis, shown on page 100 of Vol. 126 U. S. Reports†, has ever been made with care to reproduce articulate speech, it has not been done with the combination of instrumentalities devised by Reis, or by any method described by him; but by the method devised by me, and in consequence of knowledge given to the world by me. It certainly never was done before the issuance of my two patents No. 174,465, and No. 186,787, nor even until after the public appearance of microphones and Blake transmitters. Certainly it was not done with the combination of instrumentalities devised by Reis. The drawings you have referred to on page 100 of Vol. 126 U. S. Reports are themselves a confession of this fact, for a telegraphic apparatus with ordinary telegraph-keys is provided for the purpose of carrying on communication. By changing the combination of instrumentalities shown by Reis, and adopting as a transmitter the ordinary Blake transmitter in commercial use, we have an entirely



different combination from that devised by Reis, operating upon an entirely different method. It is, in fact, my combination and my method. No sensible sounds, even of a musical character, so far as I know, were produced by the action of undulatory currents from the core of an electro-magnetic coil operating like the Reis receiver, until after the public appearance of microphones and carbon transmitters. In my paper of May 10, 1876, in paragraph 15, I said :

“ Although sounds proceed from the armatures of electro-magnets under the influence of undulatory currents of electricity, I have been unable to detect any audible effects due to the electro-magnets themselves. An undulatory current was passed through the coils of an electro-magnet which was held closely against the ear. No sound was perceived until a piece of iron or steel was presented to the pole of the magnet. No sounds either were observed when the undulatory current was passed through iron, steel, retort-carbon, or plumbago. In these respects an undulatory current is curiously different from an intermittent one.”

You have given no date for Professor Cross's experiment, but it is obvious that the Blake transmitter, which Professor Cross states he employed, must have been made after the issuance of my patents No. 174,465 and No. 186,787, because no such instruments as Blake transmitters were known before. The experiments referred to, therefore, must have been made after the issuance of my aforesaid patents.

Cross-Int. 406. In your preliminary statement in the *Harmonic Interferences*, you say :

“ I understood that a patent in this country could not be obtained without models.” . . .

Do you remember when it was that you obtained this information that a patent in the United States could not be obtained without models, and how you happened to obtain that information?

Ans. I did not obtain that information at all. It was simply an idea that was in my own mind on account of my ignorance of patent matters. I afterwards found out that it was a mistake.

Cross-Int. 407. When was it that you found out that it was a mistake?

Ans. I do not know, but certainly I knew this early in 1875, as no model of the autograph-telegraph was required, for which I

received patent No. 161,739, dated April 6, 1875. I allude to the autograph-telegraph shown in Fig. 2 of that patent.

Cross-Int. 408. What caused you to think that no model was required in the autograph-telegraph case, referred to in your last answer?

Ans. Because I was never asked for a model, and the patent, notwithstanding, issued to me. Certainly I presumed that my solicitors would have informed me if a model was required, and I should have been very happy to have made one for the Patent Office, although it would have been an expensive matter for me to do so.

Cross-Int. 409. I conclude from your last answer that you never constructed a model of the apparatus illustrated in the drawing of your patent, No. 161,739, or of any part of such apparatus. Am I justified in making this conclusion from what you have said?

Ans. No. My remarks had reference to preparing a model for the Patent Office of the autograph-telegraph shown in Fig. 2, and claimed in Claim 3. A model of a part of such apparatus was, however, filed on March 10, but whether it illustrated anything claimed in the claims of that patent, I am not sure. It may have been one of the circuit-interrupters and one of the tuned-reed receivers. I made three distinct and separate applications for inventions in which such transmitters and receivers were employed. I allude to the applications made February 25, 1875; March 6, 1875, which issued as patent No. 161,739; and March 10, 1875. The instruments referred to were not claimed in the patent No. 161,739.

Cross-Int. 410. I gather from your last answer that you did file a model as a part of the application for letters patent of the United States filed in the United States Patent Office on the sixth day of March, 1875, upon which letters patent No. 161,739 issued?

Ans. I find by reference to the file-wrapper and contents that I did file a model as a part of the application for letters patent of the United States. Such model was filed on the tenth day of March, 1875. I certainly knew in the spring of 1875, and probably learned

from my solicitors in Washington, that I had been mistaken in the idea you have quoted in Cross-interrogatory 406, that "a patent in this country could not be obtained without models." I am confirmed in this by the fact that the file-wrapper and contents of my application of February 25, 1875, contains the following endorsement by the Examiner:

"The dwg. & Speen in this case are sufficient for the examination.
Z. F. WILBER, Exr."

Cross-Int. 411. The application for the patent No. 161,739 was filed in the Patent Office on March 6, 1875, as appears from the official print of the specification, and also from a certified copy of the file-wrapper and contents of the application; but the model, you say, was not filed until March 10, 1875. Why was it that the model was not filed and deposited with the rest of the application, of which it was to form a part?

Ans. I do not know. I may say that another application was filed on March 10, and model for that application was filed on the same day, as appears from the file-wrapper and contents which I have consulted. It is possible that the same model served for both applications.

Cross-Int. 412. Among the papers constituting the file-wrapper and contents in the matter of your application of February 25, 1875, I find the following letter:

HON. COMMR OF PATENTS

Sir: In this matter we ask that the application may be sent forward to the Examiner without the models. The latter will be filed in a day or two; they are now in this city but are being used by the inventor at present.

Respectfully

POLLOK & BAILEY
Attys.

And on the certified copy of the file-wrapper I find the following lead-pencil entry opposite the word *Model*: "see letter within." Do you know whether or not a model ever was filed in that case, either before or after the examination? I ask this question because the attorneys say in their letter that a model will be filed in a day or two, and the entry on the file-wrapper merely refers to this letter of the attorneys.

Ans. On the letter which you have just read appears the note of the Examiner which I quoted in my answer to Cross-interrogatory 410, viz :

“The dwg. & Specn. in this case are sufficient for the examination.

Z. F. WILBER, *Exr.*

Approved.

ELLIS SPEAR

Actg. Comr”

The file-wrapper gives no indication that any model was subsequently filed in the case, and I do not think that any model was ever filed, or required by the Commissioner.

Cross-Int. 413. I was aware that the certified copy of the file-wrapper and contents did not show that a model had been filed, and I was also aware that the Examiner had made the entry that the drawings and specification in the case were sufficient or the examination. The object of my question was to ascertain whether, within your knowledge, a model ever had been filed in the case, or had not been filed ; and I understand from your answer that you do not think a model was ever filed in the case, or required by the Commissioner. Do you know positively whether or not a model has been filed with that application, or has not been filed ?

Ans. I feel pretty sure that no model was ever filed in this case ; as sure as one can be in testifying of matters that occurred so long ago. Of course the letter which you have quoted in your last preceding cross-interrogatory stated that I had models, that they were then in the city, and that I was using them. There was no difficulty, therefore, in supplying models, if the Commissioner required them. To the best of my knowledge and belief, no models ever were required, and, therefore, none were filed.

Cross-Int. 414. No patent has ever issued, I believe, upon the application referred to by you in your last preceding answer, up to the present time. Is that so ?

Ans. That is so ; and that is just the reason that I did not in my answer to Cross-interrogatory 407 allude to this specification in proof of the fact that I knew, in 1875, that a patent could be obtained in this country without models. I preferred, therefore, to allude to my application of March 6, 1875, because it actually issued

as a patent, viz, No. 161,739, of April 6, 1875. I know that no model of the autograph-telegraph described and claimed in that patent was ever filed in the Patent Office, because the autograph-telegraph shown and described in my said patent, illustrated in Fig. 2 and claimed in Claim 3, had not been constructed as a whole at the date of the issue of that patent. Whatever model was filed illustrated only a portion of the apparatus employed. I may say also that the model filed with my application of March 10, 1875, did not illustrate the matter claimed in that specification, for I am quite sure that, whatever the nature of the model filed with that application, it was not a circuit-breaking cylinder like that shown in the drawings of the specification, nor was it, indeed, any kind of

“apparatus for making and breaking said circuit a definite number of times per second or other unit of time, with makes and breaks of equal duration, substantially in the manner described, so that the positive and negative impulses thereby induced in the line wire shall succeed each other at equal intervals of time.”

I assert this because I had no such apparatus for illustrating that in Washington, in February or March, 1875.

Cross-Int. 415. I gather from your last answer that you got the impression that models were dispensed with, or sometimes dispensed with, because the models forming a part of the applications referred to in your last answer illustrated only a portion of the apparatus shown in the drawings of said applications. Is that the fact?

Ans. No. I did not get this impressson simply from the circumstances referred to. About the end of February or beginning of March, 1875, I learned from my solicitors in Washington that the filing of a model was a matter entirely within the discretion of the Commissioner of Patents, and that no model at all need be filed unless he required it.

Cross-Int. 416. Was any patent ever granted to you prior to March 7, 1876, based upon an application of which a model did not constitute a part?

Ans. My patent for the autograph-telegraph, No. 161,739, dated April 6, 1875, was based upon an application of which a model of the autograph-telegraph did not constitute a part. The model actually filed illustrated a part only of the invention described and

claimed in the patent. This was the only patent granted to me before March 7, 1876.

Cross-Int. 417. I notice in your previous answers you have called the patent No. 161,739 a patent for autograph-telegraph, whereas the certification of the Commissioner of Patents reads as follows :

"This is to certify that the annexed is a true copy from the Records of this Office of the Letters Patent granted Alexander Graham Bell, Thomas Sanders, and Gardiner G. Hubbard, April 6, 1875, number 161,739, for Improvement in Transmitters and Receivers for Electric Telegraphs."

Why have you not designated this patent according to its official title?

Ans. I wished to direct special attention to one particular kind of electric telegraph to which the invention referred. The transmitters and receivers shown in my patent, when combined in the manner described and illustrated in Fig. 2, constituted the autograph-telegraph claimed in my third claim, and the patent had reference mainly to that autograph-telegraph.

Cross-Int. 418. I conclude from the language used in the letter of your attorneys, in your February 25, 1875, application, to which your attention has heretofore been called, particularly the words: "We ask that the application may be sent forward to the Examiner without the models. The latter will be filed in a day or two," that it was the intention of both yourself and your attorneys to deposit a model as a part of the February 25, 1875, application. Is my conclusion correct?

Ans. Certainly ; if the Commissioner had required it.

Cross-Int. 419. What became of the model referred to in your last answer?

Ans. Some of the models referred to were filed with the applications of March 6, 1875, and March 10, 1875. I think I took the rest of the apparatus away with me when I left Washington on or about the second day of March, 1875 ; and exhibited the instruments in operation in New York, to Mr. Orton, president of the Western Union Telegraph Company, within a few days of that date.

Cross-Int. 420. Was the model which you originally intended to

file with the February 25, 1875, application, afterwards filed with either the March 6 or March 10 application?

Ans. I cannot say. I do not remember exactly the nature of the models filed with these applications. I left Washington about the 2d of March, 1875. The models were not filed until the 10th of March. While I do not remember exactly what those models were, I do remember what they were not, and can assert that it was not a model of an autograph-telegraph that was filed with the application for my autograph-telegraph patent; nor an apparatus for producing makes and breaks of equal duration, that was filed with my application of March 10, 1875.

Cross-Int. 421. Was this model which you intended to file with your February 25th application ever shown to Z. F. Wilber, the Examiner whose name appears in the files of the case?

Ans. I don't know. It may be perfectly possible that he saw my models in operation in Washington, as they were exhibited to quite a number of people. I cannot pretend to say whether or not Mr. Wilber was among those who came to see the apparatus. I was not acquainted with him, and would not therefore be likely to remember his presence unless it had been specially stated that he was the Examiner. I do not remember his being present at any of the exhibitions. He may have been, but I cannot tell now.

Cross-Int. 422. When did you first become acquainted with Mr. Z. F. Wilber, the Examiner mentioned in the last question and answer?

Ans. I never became acquainted with him sufficiently to recognize him by sight, without being told who he was. I do not know when I first saw him. It is not at all unlikely that I saw him in Washington at the end of February or beginning of March, 1875, but I cannot tell now. If so, that was the first time. I do not think I have met him more than half a dozen times in the course of my life; of course I may have done so, but that is my impression.

Cross-Int. 423. Do you remember meeting any Examiner of the Patent Office on the occasion of your first visit to Washington?

Ans. I do not remember having done so, at the present moment. It may be possible, but I have not refreshed my memory on the subject. I think it would be very strange if I had not met some of the

Examiners at that time, but I have no recollection on the subject now.

Cross-Int. 424. When did you first meet any Examiner of the Patent Office?

Ans. I think I must have met an Examiner of the Patent Office in February or March, 1875, although I have no distinct remembrance of the circumstance. This would be the first time.

Cross-Int. 425. Do you remember ever writing a letter in which you call attention to the fact that you had met one of the Examiners of the Patent Office?

Ans. I have not refreshed my recollection. I think it very likely that I may have alluded to meeting one of the Examiners of the Patent Office in some letter, but I do not remember just now exactly what the letter is, or when it was. I have no doubt if I could see the letter it would refresh my remembrance.

Cross-Int. 426. In your last answer yesterday, you referred to undulatory currents of electricity. In order that I may clearly understand what you mean by undulatory currents of electricity, I will call your attention to the description of the Helmholtz apparatus contained in your London lecture. In that lecture you say :

“ His apparatus is shown in Fig. 18. Tuning-forks of different pitch are placed between the poles of electro-magnets (a^1 , a^2 , etc.), and are kept in continuous vibration by the action of an intermittent current from the fork b . ”

Suppose the circuit-breaking apparatus of Helmholtz is taken from the circuit, and the wires simply united together; and further, suppose that one of the tuned receiving forks is vibrated, would what you term an undulatory current be formed in the circuit?

Ans. In my patent No. 174,465, of March 7, 1876, I have fully described what I mean by an undulatory current of electricity, and how it is distinguished from an intermittent current, like that employed in the Helmholtz apparatus shown in Fig. 18 of my London lecture. In regard to the proposed change in the combination illustrated in Fig. 18, I am a little doubtful as to what you mean by the term circuit-breaking apparatus. I observe that each prong of the transmitting tuning-fork carries a wire which makes and breaks contact with mercury, so that it looks as if there were two circuit-breaking

arrangements shown in the diagram ; and I do not pretend to know exactly how the apparatus works. I shall suppose, therefore, that you mean to take out from the circuit everything between the points *g* and *k* ; or, in other words, to remove everything from the circuit except the battery cells and the receiving instruments ; using an unbroken circuit, and a continuous current from the battery. I further understand that, under these circumstances, you ask in substance, whether the mechanical vibration of the prongs of one of the tuning-forks between the poles of its electro-magnet will occasion in the circuit an undulatory current, in the sense in which that term is used in my patent of March 7, 1876, No. 174,465. As you have not stated how the fork is to be vibrated, I shall suppose the prongs to be plucked with the fingers, and the tuning-fork then allowed to vibrate freely between the poles of its electro-magnet. And you ask whether that free vibration will occasion in the circuit an undulatory current, in the sense I use that term in my patent of March 7, 1876. I think it will.

Cross-Int. 427. It is a fact, is it not, that in the Helmholtz apparatus to which you have referred in your last answer, the rates of vibration of the receiving tuning-forks are either the same or a multiple of the rate of vibration of the transmitting tuning-fork ?

Ans. They are all multiples of the rate of vibration of the transmitting fork. In Appendix VIII. of Mr. Alexander J. Ellis's translation of Helmholtz's work is described and shown the vowel apparatus of Helmholtz referred to in my London lecture and illustrated in Fig. 18. From this I understand that as circuit-breaking wires are attached to each prong of the transmitting fork,

"each vibration of the fork makes the current twice ; once when the upper prong dips into the cup of mercury *h*, and once when the lower prong dips into the cup *i*."

Under the arrangement shown in Fig. 18 of my London lecture, therefore, it appears that the receiving tuning-fork of lowest pitch should be an octave above the tone of the transmitting fork, and that in order to actuate this fork by a transmitting fork of its own pitch, it is necessary to make a change in the transmitting part of the appa-

ratus. In Appendix VIII. to Helmholtz's work, referred to above, referring to the vowel apparatus as shown in Fig. 18 of my London lecture, the translator says :

“The arrangement just described is preferable when the fork 1 is the Octave above the fork *b*. But if the fork 1 makes the same number of vibrations as the fork *b*, the wire *i k* must be removed, and both the other wires ending in *i* must be connected with *h*.”

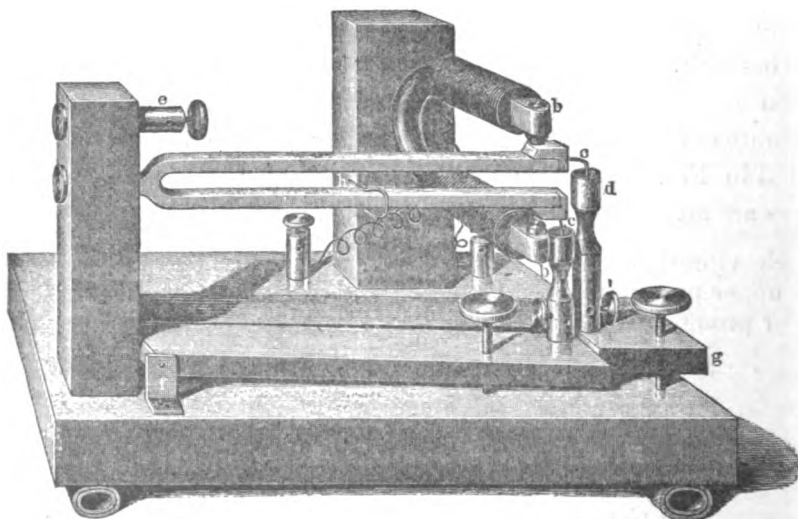
Such a change would omit one of the circuit-breaking devices and retain the other alone.

Cross-Int. 428. The circuit-breaking tuning-fork apparatus which is diagrammatically illustrated in your London lecture which has been offered in evidence is illustrated by perspective drawing Fig. 33,* on page 178 of the translation of Helmholtz's work by Alexander J. Ellis, published in London by Longmans, Green & Co., in 1875 — is it not?

Ans. I believe so.

Cross-Int. 429. And the receiving instrument illustrated in Fig.

Fig. 33.



32,* page 176, of the translation of Helmholtz referred to in my last question, is substantially the same in electrical and acoustical operation as any one of the receiving tuning-forks which are illustrated diagrammatically in your London lecture. That is so, is it not?

Ans. So I understand.

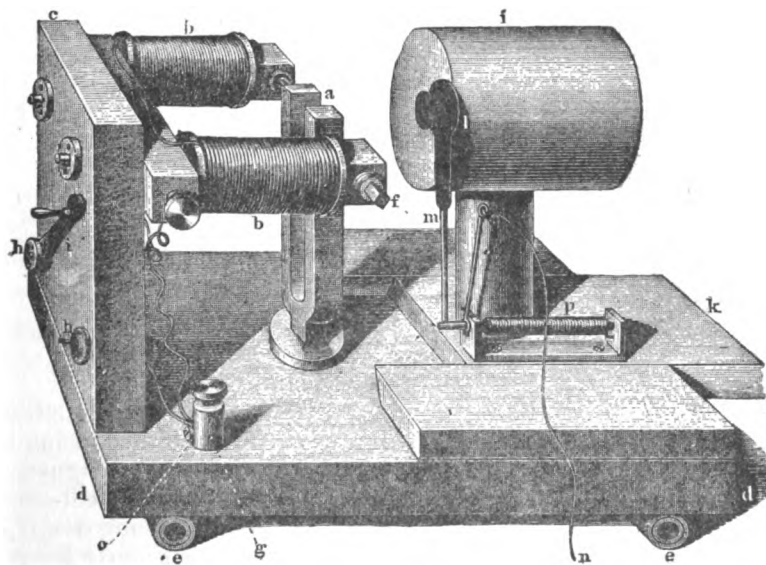
Cross-Int. 430. Having reference to your English patent which has been offered and filed in evidence by the defendants in this cause, will you please state whether or not a disclaimer has ever been filed in the British Patent Office, so far as you know?

Ans. I believe so, on account of prior publication of my invention by Sir William Thomson in his address before the British Association for the Advancement of Science, describing what he saw at the Centennial in Philadelphia; and on account of his public exhibition of the telephones I presented to him in July, 1876. On account of the patent laws of England it became necessary to disclaim all of my own inventions that had been publicly described or shown in England before the date of my British patent.

Cross-Int. 431. Having reference to your allusion to undulatory currents contained in the extract referred to in your answer to Cross-

*

Fig. 32.



question 405, I will ask you, for the purpose of obtaining a clear understanding of your meaning of the words "undulatory currents," as used in that answer, that you suppose two Helmholtz receivers, each similar to that illustrated in Fig. 32 on page 176 of Ellis's translation before referred to, to be placed in an ordinary battery-circuit, and I will ask you further to suppose that one of the tuning-forks is mechanically vibrated: In such a case, would an undulatory current be created upon the line?

Ans. If one of the tuning-forks should be mechanically vibrated so as to produce its musical tone, I have no doubt that the sonorous vibration of the fork would occasion an undulatory current upon the line.

Cross-Int. 432. In the case supposed in the last answer, would one of the Helmholtz tuning-forks be set in vibration by the mechanical vibration of the other?

Ans. In the case supposed, as I understand the question, there are only two such tuning-fork receivers in the circuit. If both tuning-forks had the same pitch or rate of vibration, I have no doubt if one of the forks should mechanically — as, for example, by plucking the prongs with the fingers — be forced to produce its musical tone, and thereby occasion electrical undulations upon the circuit, that the other fork also would be thrown into sonorous vibration.

Cross-Int. 433. Referring to Fig. 5 of your patent No. 174,465: If the armature *c* is mechanically vibrated, will the electrical and acoustical operation of the apparatus be the same as that of the supposed Helmholtz apparatus referred to in the last question and answer?

Ans. I would prefer to say that the electrical and acoustical operation of the Helmholtz tuning-fork apparatus in the hypothetical experiment suggested would be similar to that of the apparatus shown in Fig. 5 of my patent No. 174,465, as described in my patent as follows:

"In illustration of the method of creating electrical undulations, I shall show and describe one form of apparatus for producing the effect. I prefer to employ for this purpose an electro-magnet, *A*, Fig. 5, having a coil upon only one of its legs *b*. A steel-spring armature, *c*, is firmly clamped by one extremity to the uncovered leg *d* of the magnet, and its free end is allowed to project above the pole

of the covered leg. The armature c can be set in vibration in a variety of ways, one of which is by wind, and, in vibrating, it produces a musical note of a certain definite pitch.

"When the instrument A is placed in a voltaic circuit, $g b e f g$, the armature c becomes magnetic, and the polarity of its free end is opposed to that of the magnet underneath. So long as the armature c remains at rest, no effect is produced upon the voltaic current, but the moment it is set in vibration to produce its musical note a powerful inductive action takes place, and electrical undulations traverse the circuit $g b e f g$. The vibratory current passing through the coil of the electro-magnet f causes vibration in its armature h when the armature $c h$ of the two instruments $A I$ are normally in unison with one another; but the armature h is unaffected by the passage of the undulatory current when the pitches of the two instruments are different."

In giving this answer, I assume the supposed Helmholtz tuning-fork apparatus to be constructed as follows: Two double-pole electro-magnets are supposed to be arranged upon a metallic circuit with a voltaic battery, no other electrical arrangements being included in the circuit. Between the poles of each electro-magnet are placed the prongs of a tuning-fork, as shown in Fig. 32 on page 176 of Ellis's translation of Helmholtz's work, and the two tuning-forks are to have the same pitch or rate of vibration. Then, as I understand the nature of the experiment, one of these tuning-forks is to be set mechanically into vibration so as to produce its musical tone: in this case, I have no doubt a mode of operation will take place similar to that I have quoted above from my patent; and the other tuning-fork in the circuit, having normally the same pitch as the first, will be thrown into sonorous vibration.

[Counsel for complainant gives notice that at the hearing of this cause he will produce the work entitled:

"ON THE
SENSATIONS OF TONE
AS A PHYSIOLOGICAL BASIS FOR THE
THEORY OF MUSIC.

By

HERMANN L. F. HELMHOLTZ, M. D.

Foreign Member of the Royal Societies of London and Edinburgh,
Formerly Professor of Physiology in the University of Heidelberg,
And now Professor of Physics in the University of Berlin.

Translated with the Author's Sanction from the Third German Edition,

With Additional Notes and an Additional Appendix,

By

ALEXANDER J. ELLIS,

B.A. F.R.S. F.S.A. F.C.P.S. F.C.P.

Past President of the Philological Society,

Member of the Mathematical Society,

Formerly Scholar of Trinity College, Cambridge,

Author of

'Early English Pronunciation' and 'Algebra Identified with Geometry.'

LONDON :

LONGMANS, GREEN, AND CO.

1875."

That he will direct particular attention to Chapter Six of the said work "On the Apprehension of Qualities of Tone," pages 174-226, and to Appendix VIII., entitled "Practical Directions for Performing the Experiments on the Composition of Vowels," pages 604-607. The work will be referred to at the hearing as in illustration of the state of the art as it existed prior to the electrical invention of Alexander Graham Bell.

Counsel for complainant offers in evidence the Disclaimer and Memorandum of Alteration of William Morgan-Brown, filed in the British Patent Office on the thirteenth day of February, 1878 :

"In the Matter of Letters Patent granted to William Morgan-Brown, of the Firm of Brandon and Morgan-Brown, Engineers and Patent Agents, of 38, Southampton Buildings, London, and 1, Rue Lafitte, Paris, for the Invention of 'IMPROVEMENTS IN ELECTRIC TELEPHONY (TRANSMITTING OR CAUSING SOUNDS FOR TELEGRAPHING MESSAGES) AND TELEPHONIC APPARATUS.' A communication from abroad by Alexander Graham Bell, of the University of Boston, Massachusetts, United States of America, Professor of Vocal Physiology, bearing date the 9th December, 1876, No. 4765."

The same is marked "Complainant's Exhibit Bell's British Disclaimer, H. L. H., Special Examiner."]

Cross-Int. 434. I wish you would examine the disclaimer and memorandum of alteration filed in the British Patent Office on the thirteenth day of February, 1878, and state whether or not any other disclaimer or memorandum of alteration has been filed in the British Patent Office affecting or relating to your English patent.

Ans. I am sure I don't know. Any disclaimer or memorandum of alteration affecting or relating to my British patent, including the disclaimer just put in evidence, was prepared and filed after I had parted with my interest in my British patent, and was done by counsel on behalf of the owners of the patent.

Cross-Int. 435. I have understood you to say in a previous answer that the reason for filing a disclaimer in England was that your invention, or a part thereof, had been published prior to the filing of the application for the British patent. Was there any other reason that you know of for the filing of this disclaimer?

Ans. I have not examined the disclaimer to ascertain this point, but I do not think there was any other reason. As I understand the matter, printed copies of my United States patents No. 161,739, of April 6, 1875, and No. 174,465, of March 7, 1876, appeared in England within a few weeks after the issuance of those patents, and this constituted publication in England, according to the British law. Again, my paper of May 10, 1876, before the American Academy of Arts and Sciences — if it appeared in any of the libraries of England before the 9th of December, 1876 — would constitute publication of the contents in England, before the date of the British patent. It would then become necessary for the owners of the patent to disclaim everything claimed or described in the patents I have named, or contained in the May 10, 1876, paper. The disclaimer, as I understand it, simply means that the inventions disclaimed were not new in England on the 9th day of December, 1876. It does not mean that these inventions were not original with myself. As a matter of fact, it was the publication of *my* inventions, not those of others, that led to the disclaimer or disclaimers filed by the owners of my British patent.

Cross-Int. 436. I notice in the disclaimer which has been offered in evidence, the following language is used :

“And whereas since the filing of the Specification in pursuance of the said Letters Patent, I, the said William Morgan-Brown, have ascertained that some of the claims made therein are too wide, and comprise, as forming parts of the said Invention, parts that were not new in the United Kingdom at the date of the said Letters Patent, by reason of descriptions thereof having been published in England before the 9th December, 1876, and in particular certain

descriptions of telephonic apparatus that had been invented and used by the said Alexander Graham Bell, in America, prior to the said date: And whereas it has been ascertained that parts of the said Invention as described in the said Specification are not of sufficient practical utility: And whereas I am desirous for the above reasons, of amending my said Specification by Disclaimer and Memorandum of Alteration, as herein-after set forth, and of confining the claims in the said Specification to arrangements of telephonic apparatus, wherein are employed plate armatures or armatures other than those carried by a membrane, and arrangements wherein are employed permanent magnets or magnets excited by batteries which are not in the main circuit or line wire:”

As you state in your last answer that you have not examined the disclaimer, I call your attention to this language used therein and ask you whether, in view of the said language, you desire to modify your preceding answers.

Ans. I desire to modify them only so far as to say that I cannot pretend to know all the opinions held by the owners of my British patent, or their counsel, that influenced the wording of the disclaimer, excepting so far as they are disclosed by the disclaimer itself.

Cross-Int. 437. You have testified on your direct examination as to certain suits which have been brought in this country upon your patents. I will ask you to carry your answer a little further, and state whether or not any suit has been brought upon your English patent, and if so, whether or not you testified in the suit.

Ans. I believe there have been law-suits in England in which my British patent was involved, but I know nothing of the details of them personally. I did not testify in any of them.

Cross-Int. 438. Were these English suits to which you refer in your last answer commenced before or after the thirteenth day of February, 1878, the date on which your English disclaimer was filed?

Ans. I don't know certainly, but my impression is that the disclaimer was filed before the British patent was involved in any suit in England.

Cross-Int. 439. Cross-interrogatory 406 was as follows:

“In your preliminary statement in the Harmonic Interferences you say: ‘I understood that a patent in this country could not be

obtained without models,' . . . Do you remember when it was that you obtained this information that a patent in the United States could not be obtained without models, and how you happened to obtain that information?"

You have called attention to an application in which it would seem from the Examiner's entry that a model was temporarily dispensed with during the examination or a part of the examination of the case; and you have called attention to a patent issued in which, as I understand it, a model formed a part of the application, although you say this model did not fully illustrate all that was claimed in the patent. I will somewhat modify the form of question, and ask you when you first obtained the information that a patent of the United States could be issued in a case where a model formed no part of the application, up to the time of its issue.

Ans. In regard to the part of your question referring to Cross-interrogatory 406, I stated in substance, in my reply to that cross-interrogatory, that I never obtained any information to the effect that a patent in this country could not be obtained without models, and that it was simply an idea that was in my own mind on account of my ignorance of patent matters, about the time I wrote to the Honorable Mr. Scudamore, Superintendent of Telegraphs in England, as stated in my preliminary statement in the *Harmonic Telegraph Interferences*. That is, such an idea was in my mind on or before the tenth day of January, 1874. I also stated in my reply to Cross-interrogatory 406, that I afterwards found out that such an idea was a mistake.

In regard to the last part of your present question, I don't know when I first obtained the information that a patent of the United States could be issued in a case where a model formed no part of the application up to the time of its issue, but I knew of this in February or March, 1875 — that is, I knew at that time that it was not necessary that a model should form a part of the application unless the Commissioner required it. I understood that the filing of a model was a matter entirely within the discretion of the Commissioner of Patents.

Cross-Int. 440. Has your attention ever been called to any patent issued prior to February or March, 1875, in which a model was not

filed or deposited at the Patent Office at some time before the actual issue and delivery of the patent?

Ans. I don't know.

Cross-Int. 441. Professor Cross has testified in this case as follows :

"Q. 74. Did you ever make any statements in regard to the electrical transmission of speech when lecturing or exhibiting the apparatus in which the tin-box receiver was used?

[*Same objection and standing objection.*]

A. I did in my lecture to the New England Conservatory of Music in February, 1872.

Q. 75. Please give, as nearly as you can recollect, this statement that you made at that time.

[*Same objection.*]

A. I do not, of course, remember my precise words, but what I said was to this effect: Professor Tourjée, who was then director of the Conservatory, and who was present at my lecture, was at that time interested in getting up a chorus for the monster 'Peace Jubilee,' as it was called, which was to be held in Boston in the following summer, and to which musicians from all over the country were expected to come. After exhibiting the apparatus I said, rather playfully, that we might hope with some such apparatus as this, with some improved form of transmitter, to be able to transmit the music of the Jubilee all over the country, or that perhaps instead of assembling the chorus together, we might have them remain at their homes and transmit the music to the auditorium in Boston. I did not suggest any way of modifying the transmitting apparatus whereby such an effect might be produced, but considered that the use of a plate receiver was a marked improvement over the receiver of Reis."

When, if ever, did Professor Cross speak to you about the transmission of articulate speech in connection with the Reis receiver or Reis transmitter?

Ans. I presume from your question that you mean to ask me when, if ever, did Professor Cross speak to me about the transmission of articulate speech by means of a Reis transmitter and receiver. He never spoke to me of such a thing, or even suggested that it was possible to transmit articulate speech by that apparatus

Cross-Int. 442. I direct your attention to Fig. 3 * of your preliminary statement in the *Harmonic Telegraph Interferences*, and ask you to describe the operation of that instrument in case the

* See page 248.

style attached to one arm of the transmitting tuning-fork remains constantly immersed in the mercury of the cup. This may, of course, as I understand, be effected by either lengthening the point of the style or raising the mercury in the cup.

Ans. I am extremely doubtful whether it would work at all. I do not think that, under such circumstances, the transmitting fork will vibrate.

Cross-Int. 443. You mean, do you, that the mechanical resistance caused by the dipping of the wire in mercury would prevent the vibration of the transmitting tuning-fork?

Ans. No. That has not anything to do with the difficulty. If the style attached to one arm of the transmitting tuning-fork remains constantly immersed in the mercury of the cup, both prongs will be constantly attracted by the poles of the electro-magnet, and never released, because the circuit is never broken. The prongs, therefore, would simply assume some resultant position in respect to the poles of the electro-magnet, and remain there without vibrating.

Cross-Int. 444. My former question should probably have been put in a different form. I will now ask you if the mechanical resistance occasioned by the weight of the style and the dipping of the same constantly in the mercury would have any substantial effect upon the vibrations of the transmitting instrument?

Ans. Not in the supposed case, for in this case there would be no vibration at all of the transmitting instrument. In the case of a *vibrating* tuning-fork the mechanical resistance occasioned by the weight of the style and the dipping of the same constantly in the mercury would theoretically have some effect in impeding the vibration of the fork; but practically it would have little or no effect if the mass of the tuning-fork was great, and the weight and diameter of the dipping wire slight. The less the mass of the tuning-fork, and the greater the weight and diameter of the wire dipped into the mercury, the more would the vibration of the tuning-fork be affected thereby.

Cross-Int. 445. Please describe the electrical and acoustical operation of the apparatus illustrated in Figs. 2* and 3 of your preliminary statement in the *Harmonic Telegraph Interferences*, when

* See page 248.

the transmitting fork thereof is mechanically vibrated, and the style thereof remains constantly immersed in the mercury.

Ans. If the transmitting fork be thrown mechanically into vibration so as to produce its musical tone, the vibration of the upper prong will cause the attached wire to dip more or less deeply into the mercury. The more deeply the conducting wire is immersed in the mercury, the greater the amount of surface of the wire in contact with it, and therefore, the less the electrical resistance of the liquid path. The less deeply the conducting wire is immersed, the greater the resistance of the liquid path. The electrical operation, therefore, depends very greatly upon the change of electrical resistance of the liquid path. If that change be very slight, there may be practically no electrical effect at all produced by the mechanical vibration of the fork, the current remaining of practically uniform intensity throughout, although theoretically an alternate increase and diminution of the liquid path occurs at every vibration of the transmitting fork, thus occasioning electrical undulations corresponding to the sonorous vibrations of the air while the fork is producing its musical tone. The electrical effect, as I have stated, depends very greatly upon the change of resistance of the liquid path during the sonorous vibration of the fork; and this again depends very greatly upon the material composing the wire that is dipped into the mercury, the diameter of that wire, and its normal depth of immersion. In the operation of the apparatus as shown in Fig. 2 and Fig. 3 of my preliminary statement in the *Harmonic Telegraph Interferences*, in which the conducting wire makes and breaks contact with the mercury, the material of the wire, its diameter, and its depth of immersion are of practically little account, so long as the wire is actually lifted out of the mercury on its ascent and makes contact with it upon its descent. But as these points are of very great importance in the case considered, and you have in your question specified no particular material, or diameter, or depth of immersion, I may say that if the wire dipping into the mercury is of such material and diameter as to offer but slight resistance to the passage of an electrical current, then the vibration of the wire in the mercury will produce little effect; and practically, where the wire is a very good conductor indeed, no electrical operation would be produced

at all by the sonorous vibration of the fork ; a current of uniform intensity persisting in the circuit, although of course, in every case, a theoretical effect is produced. On the other hand, if the material and diameter of the wire be such as to offer a very great resistance to the passage of the current, then the vibration of the wire in the mercury will produce a very material effect upon the resistance of the circuit. The difference between the maximum and minimum resistance will be greater than in the former case, and the undulatory action on the current more marked. Thus, the greater the resistance of the wire that is dipped into the mercury, the greater the electrical operation produced by the sonorous vibration of the fork ; the less its resistance, the more nearly does the apparatus approach a condition in which the vibration will produce no electrical operation at all.

In regard to the depth of immersion : The vibration of the wire will produce comparatively little electrical effect if the normal depth of immersion be great, and a comparatively great effect if the normal depth of immersion be slight. For example, suppose the wire to be moved up and down in the mercury to the extent of one one-hundredth of an inch. Now, if the normal depth of immersion be one inch, the vibration of the wire will cause a change in the amount of surface in contact with the mercury of only about one *per cent.* of the whole surface normally in contact with the mercury, whereas, if the normal depth of immersion be only about one one-hundredth of an inch, a similar vibration of the wire would produce a change of more than fifty *per cent.* in the amount of surface normally in contact. The electrical resistance is least when the surface in contact with the mercury is greatest, and *vice versa*. From this it follows, that the electrical change produced by any given vibration of the tuning-fork is least when the normal depth of immersion is greatest, and greatest when it is least — it always being understood that the normal depth of immersion must be sufficient to prevent the wire from leaving the surface of the mercury at the highest point of its swing. If the normal depth of immersion be very great, practically no electrical effect will be produced by the sonorous vibration of the fork, and in order that there should be any substantial electrical operation at all, the normal depth of immersion must be slight. In considering then, the operation of the apparatus illustrated in Figs. 2 and 3 of my pre-

liminary statement in the *Harmonic Telegraph Interferences*: when the transmitting fork thereof is mechanically vibrated, and the style thereof remains constantly immersed in the mercury, the best electrical effects due to the vibration of the fork are produced by making the style of a poor conducting material, and by making the normal depth of immersion in the mercury as slight as possible consistently with the condition that the circuit shall remain unbroken.

When the apparatus is arranged exactly as shown in Fig. 2 or Fig. 3, so that the circuit is made and broken at each vibration of the fork, the electro-magnet is of service as a means of sustaining continuously the vibration of the transmitting fork; but in the case considered, where the end of the style remains constantly immersed in the mercury, the electro-magnet of the transmitter is of no use, and is actually a hindrance to the vibration of the fork. The poles of the electro-magnet pull the prongs with greater and greater force as the style dips more and more deeply into the mercury, — that is, when the prongs are normally moving away from the poles. When, then, the fork is thrown mechanically into sonorous vibration, the effect of the electro-magnet is to check the vibration of the prongs and bring them more speedily to rest than if there had been no electro-magnet at all connected with the transmitting instrument.

You have also asked me about the acoustical operation of the apparatus; but it is obvious that in the case considered no acoustical effect will be produced other than the musical tone due to the mechanical vibration of the transmitting fork, unless the key K, Fig. 2 or Fig. 3, should be depressed so as to place the receiving instrument in the same circuit with the transmitter. In the drawing, Fig. 2 or Fig. 3, the transmitter is in a local circuit not connected with the receiver; but by the depression of the key K the local circuit is broken and contact established with the line wire leading to the receiver. The tuning-fork of the receiver has normally the same pitch as that of the transmitter. If, then, we depress the key K and set the transmitting fork mechanically into vibration so as to produce its musical tone, and arrange the style so that it shall not break contact with the surface of the mercury, the vibration of the transmitting fork will occasion upon the circuit containing the receiver electrical undulations analogous to sonorous vibrations, and the prongs of the

receiving fork will be thrown into vibration by the varying attraction of its electro-magnet, thus producing a musical tone of similar pitch to that of the transmitter. The acoustical effect will be loudest when the electrical undulations are greatest; that is, when the difference between the maximum and minimum intensity of the current is greatest. The same conditions, therefore, that produce the greatest electrical effect by the vibration of the transmitting fork also produce the greatest acoustical effect from the receiving instrument. Hence, in order to produce the greatest acoustical effect, the style carried by the transmitting fork should be of poor conducting material, and the end of the style should dip into the mercury as slightly as possible consistently with the condition that the circuit must remain unbroken.

Cross-Int. 446. I understood from your statement in the *Harmonic Interferences* that the apparatus illustrated in Fig. 2 was constructed in West Newton Street, Boston, and that the instruments shown in Fig. 3 were constructed and used by you in the year 1873. I intended my question to apply to the instruments so constructed by you, and not to hypothetical instruments. With this understanding will you please state what effect the mechanical vibration of the transmitting tuning-fork before the cores of the electro-magnet has upon the current flowing through the coils thereof? Supposing, of course, as in the last preceding question, that the style is constantly immersed in the mercury and that the circuit is thus kept closed.

Ans. I am sure I do not quite understand how you desire me to answer the question. It seems to me that you are imposing hypothetical conditions which did not exist in the apparatus as it was actually constructed in 1872 and 1873, and you have not stated how the transmitting fork was to be thrown into mechanical vibration. If you limit me to the actual instruments constructed in 1872 and 1873 I may say that they were of such crude manufacture that it would be extremely difficult for me to answer your question satisfactorily. If you mean to put a hypothetical case of instruments operating substantially as shown in the drawings Fig. 2 and Fig. 3, and under the most favorable conditions, your question would be a less difficult one. As I am desirous of answering every question frankly, fully,

and fairly, I would be glad to know how you would like me to consider the question.

Cross-Int. 447. In answering the question, you may suppose that the transmitting tuning-fork is put in vibration by any method known in the art prior to the time when it was made and used by you, which does not break the circuit. You may even suppose that it was put in vibration by a blow imparted by any substance.

Ans. I am afraid I shall have to consider your question as a hypothetical one, for I do not know how I could, by mechanical means, produce a satisfactory vibration of the transmitting fork with the instruments actually constructed by me in 1872 and 1873. The tuning-forks were of small size, and the wire attached to one of the prongs caused that prong to have a slightly different rate of vibration from the other, so that it probably would not continue in vibration after being struck. The wire dipping into the mercury cup also was of good conducting material, and not suitable for an experiment such as has been described in my answer to Cross-interrogatory 445. I doubt whether the apparatus actually constructed by me in 1872 and 1873, and shown in Figs. 2 and 3 of my preliminary statement in the *Harmonic Telegraph Interferences*, would practically have operated in the manner described in my answer to Cross-interrogatory 445. I understood that question to refer to a purely hypothetical experiment, with instruments substantially similar to those shown in Figs. 2 and 3, and not to experiments with the actual apparatus constructed by me in 1872 and 1873.

Cross-Int. 448. The object of my question was simply to ascertain what effect, if any, upon the circuit, is produced by any movement or any vibration of the prongs of the transmitting tuning-fork in the presence of the magnetized cores. With this further explanation, perhaps you will better understand the preceding question.

Ans. I will consider the question as relating to a hypothetical experiment; for, as I have said, I do not know how practically I could have caused a continuous vibration of the transmitting fork by mechanical means with the actual apparatus constructed by me in 1872 and 1873.

Referring, then, to Figs. 2 and 3 of my preliminary statement in the *Harmonic Telegraph Interferences*, I shall suppose the transmit-

ting fork to be kept in continuous vibration by mechanical means, producing continually its musical tone. I shall further suppose that the style dipping into the mercury is of poor conducting material, and that its normal depth of immersion is as slight as possible consistently with the condition you impose — that its end shall be continually immersed. I shall further suppose that the key is depressed so as to throw the receiver into the same circuit with the transmitter. Under these circumstances, it is extremely difficult to say exactly what would be the electrical and acoustical operation of the apparatus. I have no doubt that the vibration of the prongs of the transmitting fork in front of the poles of its electro-magnet would cause magneto-electric impulses, but the strength of these impulses would depend upon the magnetical condition of the core of the electro-magnet; and this would be constantly changing on account of the variation of resistance at the mercury cup, due to the vibration of the style in the mercury. The problem is a complicated one. A double effect will be produced — a variable-resistance effect at the mercury cup, and a magneto-electric effect in the coils of the electro-magnet of the transmitter. All I can say is, that upon the circuit an effect would be produced which would be the resultant of these two. I do not know how we can decide from theoretical considerations alone, how far the acoustical effects produced from the receiver when the electro-magnet is retained in the transmitting instrument, would differ from those produced when the electro-magnet of the transmitter was removed. There would undoubtedly be some difference due to the superposition of magneto-electric currents upon the variable-resistance effects produced by the vibration of the style in the mercury.

Cross-Int. 449. In your preliminary statement in the *Harmonic Interferences* you say :

“So far as I have found out from Mr. Gray’s patents, his invention at that time (end of September or beginning of October, 1874) consisted of nothing more than a method of transmitting sound through living tissue, no claim being laid to the practical application of telephony to the simultaneous transmission of messages along a single wire.”

To what patents of Mr. Gray do you refer in that statement, and when did you have occasion to consult or examine them?

Ans. I do not know at the present time what patents of Mr. Gray the statement has reference to, but presume it had reference to such patents as he had applied for before the beginning of October, 1874. My preliminary statement was signed on April 27, 1876, so I presume that I must have read through these patents or looked them over before that date, with sufficient care to be able to make the statement quoted. I cannot remember at the present time what sort of examination I myself gave personally to the patents referred to, but I am inclined to think that I was informed by counsel, during the preparation of the preliminary statement, that in these patents Mr. Gray had laid no claim to the practical application of telephony to the simultaneous transmission of messages along a single wire, and that I verified the statement by looking over the patents myself.

Cross-Int. 450. In the paragraph of your preliminary statement in the *Harmonic Interferences* immediately succeeding that referred to in my last question, you allude to an article in *The Commonwealth*, descriptive of Mr. Gray's invention, using the following language :

"After considerable delay, a caveat was completed and forwarded to Mr. Hubbard in Washington, to be deposited in the Patent Office. The next day an article appeared in '*The Commonwealth*,' descriptive of Mr. Gray's method of transmitting sound telegraphically. At the conclusion of the article, allusion was made to the simultaneous transmission of messages by means of musical notes, as an invention recently made by Mr. Gray; and apparatus was described almost identical with that mentioned in my caveat. I have reason to suppose that this article was written by Mr. Hayes."

To what date or period do you refer by the words, "The next day an article appeared" . . . etc.?

Ans. I presume that the caveat was forwarded to Mr. Hubbard on the thirteenth day of November, 1874, as the article alluded to was published in *The Commonwealth* on Saturday, November 14, 1874; the caveat, however, was sworn to on the twenty-seventh day of October, 1874.

Cross-Int. 451. Was any testimony ever taken in the *Harmonic Interferences* referred to in your preliminary statement just mentioned? This question does not refer to preliminary statements which are merely *ex parte* affidavits.

Ans. Testimony was taken on my behalf, but I understand that no testimony was taken on behalf of Elisha Gray or Paul La Cour.

Cross-Int. 452. Do you know who now owns the application of Elisha Gray which was involved in the *Harmonic Interferences*?

Ans. No; I do not know.

Cross-Int. 453. You say, in answer to the sixth question: "Very shortly before my leaving Great Britain, in 1870, I procured a copy of the French edition of his work" (meaning Helmholtz's work). Was this in 1870; and was your knowledge of the French language sufficient at that time to enable you to thoroughly understand the description of Helmholtz's apparatus?

Ans. I think it must have been in 1870 that I purchased the work, but I cannot pretend to be precise about the date. My knowledge of the French language in 1870 was sufficient to enable me to understand untechnical language without much difficulty. I remember, however, that I had considerable difficulty in understanding Helmholtz's book. It was a matter of study with me to make the meaning out. I think I came to understand, by study, the acoustical operation of the Helmholtz vowel apparatus, but not the electrical operation. I may say, that a very considerable portion of the book remains to me, even to-day, as a sealed volume, even in the English translation. I allude to the mathematical parts of the work.

Cross-Int. 454. Do you know when the first German edition of Helmholtz's work entitled, "*Die Lehre von den Tonempfindungen als physiologische Grundlage für die Theorie der Musik*," was published?

Ans. In Mr. Ellis's translation from the third German edition, the statement is made on the authority of the translator, Mr. Ellis, that Professor Helmholtz's treatise mentioned was first published in 1862.

Cross-Int. 455. Did you ever visit America before August, 1870, the date on which you say you arrived in America?

Ans. No.

Cross-Int. 456. Can you make your answer to Question 9 a little more definite, and give the exact date of your arrival in America; and state what part of America you first visited?

Ans. I came to America with my parents, and landed at Quebec,

in August, 1870. I am not quite sure of the exact date, but think it was the first day of August, 1870. We went directly from Quebec to Paris, Ontario, remaining there about one week, and then settled at Tutelo Heights, near Brantford, Ontario. I resided there with my parents until I came to the United States.

Cross-Int. 457. Having reference to your answer to Question 10, had you ever been in the United States prior to April 1, 1871, when, in response to the invitation of the Board of Education you came to Boston?

Ans. I had not.

Cross-Int. 458. You have spoken in your testimony of a number of journeys between Brantford, Ontario, and Boston. What States of the United States did you travel through on those journeys?

Ans. My usual plan was to travel *via* Suspension Bridge, Niagara Falls, thus passing through the States of New York and Massachusetts. On one or two occasions I traveled *via* Montreal, in which case, I presume I passed through the States of Vermont, New Hampshire and Massachusetts, or perhaps Maine and New Hampshire.

Cross-Int. 459. Was the parent of your pupil George Sanders, referred to in your answer to Interrogatory 14, the person who became pecuniarily interested in your inventions?

Ans. Yes. I allude to Mr. Thomas Sanders, of Haverhill, Mass.

Cross-Int. 460. You have heretofore alluded to a patent No. 161,739, dated April 6, 1875, and two applications for letters patent filed February 25, 1875, and March 10, 1875, all of which have been offered in evidence. Did you, prior to the fourteenth day of February, 1876, file any other application for letters patent of the United States besides the three that I have mentioned?

Ans. I do not think so.

Cross-Int. 461. In your answer to Question 18, I understand you to say that the inventions which culminated in the patent and applications referred to in the last preceding question originated before you came to this country to reside permanently, in October, 1872. Is my understanding correct?

Ans. The idea of multiple telegraphy had originated in my mind before I came to the United States to reside permanently, in October, 1872.

Cross-Int. 462. Was the apparatus described in your answer to Interrogatory 19 the same in all respects as the apparatus of Helmholtz to which you refer in the same answer?

Ans. No. Not in all respects. I think in some respects it differed materially.

Cross-Int. 463. Please describe the points of difference referred to in your last answer.

Ans. The earlier form of apparatus constructed by me in October, 1872, is shown in Fig. 2 of my preliminary statement in the *Harmonic Telegraph Interferences*, but I find that in my answer to Interrogatory 19 I have not described that apparatus, but the apparatus shown in Fig. 3 of my preliminary statement, which was not constructed until 1873, although from the language of my answer to Interrogatory 19 it would seem as though the apparatus described referred to the earlier form constructed in October, 1872. The Helmholtz apparatus for the artificial production of vowel sounds, referred to in my answer to Interrogatory 19, is shown in Fig. 18 of my London lecture. The same apparatus is more clearly shown, because on a larger scale, on page 606 of Ellis's translation of Helmholtz's work, several times referred to in the course of this deposition. It is therein designated Fig. 64. It is to be understood, as Helmholtz himself states, that the prongs of the transmitting fork are located between the poles of the electro-magnet, as shown in the picture of that transmitting apparatus, Fig. 33, on page 178 of Ellis's translation, and that the electro-magnet *f*, in Fig. 64 of the same book, or in Fig. 18 of my London lecture, is shown out of position in order better to illustrate the electric circuits. It is stated in Appendix VIII. of Ellis's translation of Helmholtz, as referring to Fig. 64* therein, that :

"*b* is the interrupting fork, and *f* its own electro-magnet. The relative position of the two last has been somewhat changed in order to make the connection of the direction of the currents more intelligible."

I shall describe some of the chief differences between this apparatus of Helmholtz and the invention illustrated by Fig. 3 of my preliminary statement in the *Harmonic Telegraph Interferences*. Fig.

* The cut referred to is Fig. 18, p. 230, *supra*, but is on a larger scale.

2 illustrates the earlier form of apparatus, but I adopt Fig. 3 * because the instruments therein shown more closely resemble the Helmholtz instruments than those in Fig. 2, and because my answer to Interrogatory 19 describes the instruments of Fig. 3. In making this comparison I shall disregard the fact that two circuit-breaking devices are shown in Helmholtz's apparatus — one attached to each prong of the transmitting fork — because the statement occurs in Helmholtz's work, that the apparatus can be worked with only one of the mercury cups shown, and this arrangement approaches more nearly the construction of my own apparatus. The invention illustrated by Fig. 3 of my preliminary statement contemplated the employment of a number of transmitting forks of different pitches and a number of receiving forks having the same pitches as the transmitters, each transmitting fork to cause the forcible vibration of that receiving fork alone with which it was in unison, upon the depression of a telegraph-key which would put the transmitter in circuit with the receivers. Fig. 3 shows one of the transmitting forks, one of the receiving forks, and one of the telegraph-keys, so as to show the mode of operation. In Helmholtz's apparatus a number of receiving instruments of different pitch are employed, but only one transmitting fork, which is permanently connected with the receiving instruments without the intermediary of any telegraph-key. The vibration of the transmitting fork, instead of causing the vibration of only one of the receivers, sets them all sounding simultaneously. In Helmholtz's apparatus the pitches of the receiving instruments are harmonics of one another; in mine they are not. In Helmholtz's apparatus one transmitting fork operates all the receivers; in mine it operates only one, so that a separate transmitting fork is required for each receiver. In Helmholtz's apparatus the receivers are continually emitting their musical tones all the time the transmitting fork is in vibration; in my apparatus the receiving instruments are normally silent all the time the transmitters are vibrating, and each receiver produces its musical tone only at the moment the telegraph-key connected with the transmitter of its own pitch is depressed, and it only continues in operation so long as the key is depressed.

*See page 248.

In the apparatus actually constructed by me, and shown in Fig. 3 of my preliminary statement in the *Harmonic Telegraph Interferences*, the tuning-forks employed were very small, the transmitting and receiving fork having the same pitch. They consisted of ordinary tuning-forks, such as you can buy in any music store, for giving the standard pitch—I think, of the violin string A. The transmitting tuning-fork used by Helmholtz was very much larger than this, and vibrated at a very much slower rate of speed. Helmholtz's fork carried two wires, one attached to each prong, whether one mercury cup or two were used; my transmitting fork had a wire attached to only one of the prongs, thus throwing the two prongs out of tune with one another, and necessitating—or rendering advisable—the loading of the other prong. I remember I used to load it with pieces of wax. In my apparatus, the transmitting fork is normally in a local circuit, not electrically connected with the receiver. No arrangement of this kind is shown in Helmholtz's apparatus. There are other differences which I do not think it necessary to call special attention to.

Cross-Int. 464. Does, or does not, Helmholtz, in his book to which you have referred in your last answer, describe or show means for cutting out one or more of the receiving forks so that one transmitting fork may be used with one receiving fork, and so that any or all receiving forks may be cut out of circuit if necessary?

Ans. Yes, and this constitutes another difference between his apparatus and mine.

Cross-Int. 465. Does the apparatus described by you in your answer to Question 20 differ from the apparatus of Laborde, described in *Comptes Rendus*, Volume 50, page 692, and *Cosmos*, Volume 17, page 514, referred to in your answer to Cross-interrogatory 377, and also in your lecture before the Academy of Arts and Sciences?

Ans. Yes. It differs materially from the apparatus of Laborde, but I cannot state the points of difference without having the article of Laborde before me in order to refresh my memory.

Cross-Int. 466. Is any result attained by the apparatus described by you in your answer to Question 20, which is not also secured by the apparatus of Laborde?

Ans. I do not think that the result was obtained by the apparatus of Laborde of sending two or more telegraphic messages simultaneously along a single wire, which was the result aimed at by my apparatus. Of course, I could tell better if I had the original article before me, but the above statement tallies with my recollection.

Cross-Int. 467. Do you mean by your last answer that Laborde did not actually and practically obtain the results mentioned therein, or that he did not describe a means for obtaining that result?

Ans. I do not think he did either, but I could tell better if I could see the article.

Cross-Int. 468. Does the apparatus described in your answer to Question 20 differ from the apparatus described or shown in English patent No. 1775, of 1863, referred to in Cross-question 377? If it does, will you please point out any result obtained by the apparatus described in Question 20, which may not also be obtained by the apparatus described in English patent No. 1775, of 1863?

Ans. My impression is that it does differ materially, but I could speak more definitely if I could see a copy of the patent referred to, so as to refresh my recollection. I do not remember, at the present time, exactly the nature of the patent that is referred to, but I am inclined to think that I looked up the reference some years ago, and came to the conclusion that there were substantial differences.

Cross-Int. 469. The Examiner, in his letter which has been heretofore referred to, filed in the matter of your application of February 25, 1875, says:

"Claim 1 is rejected on patent to Bell, 161, 739, April 6, 1875. — 'Teleg. Reed' — and a description in *Comptes Rendus*, 1860, Volume 50, page 692, a copy of which may be found in the U. S. Patent Office Library."

The claim thus rejected is as follows:

"1. The method herein described of transmitting two or more telegraphic signals or messages simultaneously along a single wire, and of receiving the same without confusion, by the employment in an electric circuit of two or more transmitters, each transmitting per second impulses differing in number from the others, in combination with receivers each tuned to a pitch at which it will be put in vibration to produce its fundamental tone by one only of the transmitters, substantially as and for the purposes set forth."

The Examiner's letter is dated July 20, 1889; and it appears that on February 27, 1892, the date of the certification, it was the last letter written by the Examiner in the case. Has any action been taken in regard to this letter by you or your attorneys since the twenty-seventh day of February, 1892?

Ans. Not to my knowledge.

Cross-Int. 470. The Examiner's letter also says:

"Claim 2 is rejected on the references cited above and English patent 1775, of 1863. — 'Duplex Teleg.'"

The claim thus referred to by the Examiner is as follows:

"2. The combination in one electric circuit of a series of intermittent circuit-breakers adapted each to throw upon the line a definite number of electrical impulses in a given time, and a series of keys, one for each circuit-breaker, for controlling the throwing of such impulses to line, substantially as described."

Has any action been taken by you or your attorneys in relation to this rejection since the twenty-seventh day of February, 1892, the date of certification?

Ans. Not to my knowledge.

Cross-Int. 471. Who made the instruments referred to in your answer to Question 22?

Ans. I myself made the instrument referred to in the first part of the answer; and the subsequent modification of it, in which the steel reed is provided with a tuning apparatus, as shown in Fig. 3 in my application of February 25, 1875, was made for me in Mr. Williams's workshop — I presume by Mr. Watson.

Cross-Int. 472. Is the apparatus referred to in your answer to Question 23 fully illustrated in Fig. 6 forming a part of your preliminary statement in the *Harmonic Interferences*, and is the apparatus referred to in your answer to Question 23 that illustrated in said Fig. 6*?

Ans. Fig. 6 illustrates the arrangement of circuit employed. Different experiments were made during November, 1873, with a similar arrangement of circuit, but with various modifications of the transmitting and receiving instruments. In some experiments the form of transmitter and receiver used is shown in Fig. 5,* the trans-

* See page 249.

mitting reed making and breaking circuit in a cup of mercury. Transmitters arranged as in Fig. 7,* so as to make and break contact with a metallic point, were also used in a similar arrangement of circuit to that shown in Fig. 6, and receiving instruments like the drawing inserted in my answer to Cross-interrogatory 363 were also employed upon a circuit, as shown in Fig. 6. In the experiment referred to in my answer to Interrogatory 23, the receiving instruments employed were of the construction shown in the drawing inserted in my answer to Cross-interrogatory 363. The transmitting instruments were either of the construction shown in Fig. 5 or Fig. 7 of my preliminary statement in the *Harmonic Telegraph Interferences*, and the arrangement of circuit as shown in Fig. 6.

Cross-Int. 473. Having reference to Question 24, and your answer thereto, were you the original and first discoverer of the fact that the reed of such a receiver as is mentioned in your answer to Interrogatory 23 could be forced to give out a sound of different pitch from that of the tone produced by its normally free vibration, or were you simply an original discoverer of that alleged fact?

Ans. I was an original discoverer of that fact. I do not know whether I was the first discoverer or not.

Cross-Int. 474. Who was present, if you recollect, when the experiment referred to in your answer to Question 23 was made?

Ans. The experiment was made in the house of Mrs. George T. Sanders, in Salem. I do not now remember who were present upon that occasion.

Cross-Int. 475. When did you first know of Koenig's capsule and Scott's phonautograph, referred to in your answer to Question 29, and where did you first see such instruments?

Ans. I first saw such instruments at the Institute of Technology, in 1872 or 1873. I probably knew of them from printed publications before.

Cross-Int. 476. Who exhibited those instruments to you when you first saw them at the Institute of Technology?

Ans. I don't know. I think either Professor Pickering or Professor Cross, but I cannot be sure.

Cross-Int. 477. You spoke, in your answer to Question 30, of an

* See page 250.

improvement which had just been made on the phonautograph by Morey. What was this improvement of Morey, and who was Morey?

Ans. I don't know. My impression is that he was a student at the Institute of Technology, and that his full name was Charles A. Morey. When I saw the phonautograph for the first time, at the Institute of Technology, it was not arranged in the manner originally devised by Léon Scott, the inventor of it, but had attached to it the improvement of Morey, which consisted of a lever of wood moved by the membrane, and having at its free end a bristle. The vibrating bristle traced a curved line upon a plane sheet of smoked glass moved horizontally underneath it. Mr. Morey published an account of his improvement — I think in the "American Journal of Science" — which will show the date better than I can remember it.

Cross-Int. 478. Was the arrangement of the stretched membrane, conical mouth-piece, and hinged lever in Scott's phonautograph, as improved by Morey, substantially the same as the arrangement of the mouth-piece, membrane, and hinged armature shown in the left-hand instrument illustrated in Fig. 7 of the drawing of your patent No. 174,465?

Ans. I think the arrangement was substantially similar; but the wooden lever of Morey did not stop short at or about the middle part of the membrane, but was continued so that the free end of the wooden lever projected considerably beyond the opposite edge of the membrane, carrying at its free extremity the bristle referred to.

Cross-Int. 479. Still referring to your answer to Question 30: I understand you to say that if a party uttered a sound into the cone of the phonautograph, he thereby caused a vibration of the membrane and its attached lever. It is a fact, is it not, that precisely the same function is performed when a person speaks into the mouth-piece A of the instrument illustrated in Fig. 7, referred to in your last answer? That is to say, in the case of the phonautograph, the vibrating membrane acts upon the hinged lever; and in case of the instrument illustrated in Fig. 7 the vibrating membrane acts upon the hinged armature?

Ans. It all depends upon what you mean by the word "function." The mode of operation of the membrane in the two cases is sub-

stantially similar, but I think that the functions are very different. In the case of the phonautograph, the function of the membrane was to cause the bristle of the lever to trace a curved line upon smoked glass. In the case of the apparatus shown in Fig. 7 of my patent of March 7, 1876, the function of the membrane *a* was to cause the armature *c* to produce electrical undulations on the circuit *E b e f g* similar in form to the air-vibrations caused by the sound uttered into the cone *A*, so that through the intervention of the armature *h* and membrane *i* of the receiving instrument, a similar sound to that uttered into *A* should be heard to proceed from *L*.

Cross-Int. 480. You say, in answer to Question 30 :

“I came to the conclusion that the phonautograph would require considerable modification to be adapted to my purpose. The membrane was loaded by being attached to a long lever, and the bristle, too, at the end of the lever, seemed to have a definite rate of vibration of its own.”

Is the instrument illustrated in Fig. 7 of your patent No. 174,465 open to the same objection which you seem to have suggested as to the phonautograph, on account of the loading of the membrane by the attached armature?

Ans. I did not look upon the mere loading of the membrane as interfering with the operation of the apparatus, as I knew that the membrane of the human ear was loaded to a very much greater extent, in proportion to its size, by the bones moved by it, than was the case with the membrane *a* of the apparatus shown in Fig. 7. Indeed, it was the contemplation of an actual anatomical specimen of a human ear, and the realization of the enormous disproportion in mass between the delicate membrane of the tympanum and the bones that were actuated by it, that led me to the form of apparatus shown in Fig. 7. The armature *c* did not form a long lever, like the wooden lever of the phonautograph, extending far beyond its point of attachment to the membrane, and forming a long, free tongue projecting beyond the opposite edge of the membrane-support, with a strong tendency to a definite rate of vibration of its own. It was not simply the loading of the membrane that I considered objectionable in the case of the phonautograph, but loading it with a lever that had a tendency to a definite rate of vibration, and with a bristle

that also had a tendency to vibrate at a definite rate. I avoided these faults in the construction of the apparatus shown in Fig. 7 by using a comparatively short lever, and fettering it at both extremities. The armature *c* is in length only somewhere about half the diameter of the membrane. One end is fettered by a loose pivoted attachment to the uncovered leg *d* of the electro-magnet, and the other end is attached firmly to the centre of the stretched membrane *a*, so that it is forced to copy the movement of the membrane faithfully, which was not the case with the tracing of the Morey phonautograph, on account of the independent vibration of the lever and the attached bristle. In the case of the phonautograph, I considered that the independent vibration of the bristle and lever caused a distortion of the form of vibration, so that the vibrations traced upon the smoked glass were not the same in form as those executed by the membrane. In the case of the apparatus shown in Fig. 7, I considered I had remedied this defect, and that the vibration of the armature *c* would necessarily be exactly the same in form as the vibration of the membrane *a*. I considered that as the membrane *a* was not more loaded than the membrane of the human ear, it should operate as well as the membrane of the human ear in transmitting vibrations. The instrument illustrated in Fig. 7 of my patent No. 174,465 is not, therefore, open to the same objection which you have quoted, concerning the operation of the phonautograph, from my answer to Interrogatory 30.

Cross-Int. 481. In answer to Interrogatory 49, you read from a letter to your father and mother, dated March 18, 1875, in which you mention your visit to Washington. Had you written to them before this time of what occurred in Washington during that visit?

Ans. Yes. I had done so.

Cross-Int. 482. I find in the printed Volume IV. exhibits in the case of *American Bell Telephone Co. et al. v. The People's Telephone Co. et al.*, a letter which is as follows :

SALEM TO BOSTON, March 5th, 1875.

DEAR PAPA AND MAMA :

Please let me hear from you soon. Let me hear all the news. I have been working day and night in Washington, so that I have been unable to see the sights as yet. Everything looks most prom-

ising. One of the first things I did on reaching Washington was to set up my apparatus so as to make four stations, A, B, C, D. My

A	B	C	D

wish was to illustrate that a message could be sent from B to C at the same time that a message passed from A to D.

I had four cells of a battery, but no acids. In order to have plenty of battery power, that the thing might work well enough, I wished six cells and a mixture of Bi-chromate of potash with some acid (I forget what).

There was only one electrician in town, and I went to him for everything, unfortunately giving my name.

He sent me down two cells of Lockwood's battery, and I was surprised that the young man who brought them came right into the parlor and stared about, to see what kind of instruments I had got.

Still further was I surprised to find that the two cells he brought *would not work*.

The young man came back with the bi-chromate solution for the other cells, but I had my suspicions aroused and did not use the solution.

To add to my distress Mr. Hubbard informed me that Mr. Orton (the president of the Western Union Telegraph Company) would be round in half an hour to see my instruments.

'The Western Union' is probably the largest corporate body that has ever existed.

It controls more miles of telegraph wire than there *are in the whole of Europe!* It was, therefore, important to have my instruments in good shape. I did my best by getting nitric acid and sulphuric acid to get the cells I had in working order. I sawed a large carbon in two, borrowed a couple of slop-basins and had the whole in working order just *half a minute* before Mr. Orton made his appearance. The instruments, by good luck, never worked better. Mr. Orton was very much interested, and said he would like to see me again, but had to go to New York that night.

Two days afterwards I was in the Capitol seeing the Senate, when a gentleman came up and tapped me on the shoulder. It was Mr. Orton. He told me that the Western Union would be glad to give me every facility in perfecting my instruments, and he gave me a hearty invitation to take my apparatus to New York, and I should have the assistance of their best electricians.

They have a special experimental room, and have at instant command thousands of cells of battery, and thousands of miles of *real* line wire to test with.

Mr. Orton said further, that he wished me distinctly to understand that the Western Union had no interest in Mr. Gray or his invention.

This is very encouraging. Mr. Orton had *previously* seen Gray's apparatus, and yet he came forward to take up mine.

In regard to the patents: My lawyers, Pollok and Bailey, found on examination at the Patent Office, that I had developed the idea so much further than Gray had done that they have applied for *three distinct patents*, in only one of which I come into collision with Gray. The first patent covers the principle of 'Multiple Telegraphy,' basing my claim upon the instruments exhibited. (These instruments require *two* lines, an up-line and down-line.)

The second patent covers the principle of using an *Induced Current*, so as to permit a single wire to be employed.

The third patent is for a 'vibratory circuit breaker,' for the purpose of converting the vibratory motion of my Receiving Instrument into a permanent *make or break* of a local circuit.

By this arrangement I can make a receiver work *any instrument whatever* that can be moved by electro-magnetism, and it is developed into a very curious form of 'Autograph Telegraph,' by means of which an autograph message or picture may be almost instantly copied. The copy is made in ordinary ink and on ordinary paper.

My lawyers were at first doubtful whether the examiners would declare an interference between me and Gray, as Gray's apparatus had been there for so long a time.

They feared I had but a poor chance, and my spirits at once fell to zero. They said it would be difficult to convince them that I had not copied. When, however, they saw the 'Autograph Telegraph' developed from the idea that of multiple telegraphy, they at once said that was a good proof of independent invention, as Gray had no such idea. It further turned out that an Examiner in the Patent Office (not, however, of electrical inventions) is a deaf-mute, and knows me personally and by reputation, and could surely vouch for the fact of my being incapable of copying Gray.

Another fortunate circumstance was this. That the very Examiner into whose hands this will come happened to be in Mr. Pollok's office one day when I called, so that I had a long interview with him, in which I explained everything to him, and I can't help thinking that he must have been convinced of my independent conception of the whole thing.

After making out our specifications and examining into the whole thing, Mr. Pollok said, 'You have a good case.' The last words he said when I left were, 'You need not fear, we shall pull you through all right.'

Whenever Gray's lawyer heard that I was in town he applied to the Patent Office to complete Gray's patent, and thus force me to a law suit.

The examiners, however, could not act in the matter for ten days, so that gave me time to get my application in in time. I am now waiting for the decision of the examining board. They will proba-

bly declare an interference. Then I shall have to have witnesses examined and prove priority.

The invention could not have come out at any better time than the present. I shall explain how.

There are two rival telegraph companies in America: The Western Union and the 'Pacific Line.'

The Western Union have hitherto enjoyed a monopoly. But last year a man invented a method of sending *four messages simultaneously* along the same wire, and the Pacific Telegraph Company bought his patent for seven hundred and fifty thousand dollars (\$750,000).

The result has been that the Pacific Company has been able to reduce their prices so as to compete successfully with the Western Union.

Now my invention comes out as a means by which thirty or forty messages may be sent simultaneously, and by which intermediate stations may communicate with one another. If the Western Union take it up it would enable them to recover lost ground. At all events it is evidently a good time to bring out the invention. I visited the Western Union telegraph headquarters in New York on my way here. I have made arrangements to spend *Saturday and Sunday* every week in New York at the West. Un. Building.

I am to have the assistance of Mr. Prescott (the author of the book you have on Telegraphy), so now I feel that all is plain sailing if I can prove priority.

Here is Boston. Much love.

ALECK.

Is this the letter referred to in your last answer, and if it is, please state when and where it was written.

Ans. It is the letter referred to in the last answer. It was written on March 5, 1875, in the train, while going from Salem to Boston. The original letter is in pencil, and I have it before me now. I notice in the copy you have read a few immaterial typographical errors. The original letter contains at the end a copy in pencil of a memorandum of agreement made and concluded on the twenty-seventh day of February, 1875, between myself and Mr. Sanders and Mr. Hubbard. This agreement, together with the letter referred to, was also in evidence in the suit mentioned, and is printed in the same record, immediately following the letter you have read. The agreement is as follows:

"Memorandum of agreement made and concluded this twenty-seventh day of February, A. D. 1875, by and between A. Graham

Bell of Salem, Massachusetts, Thomas Sanders of Haverhill, Massachusetts, and Gardiner G. Hubbard of Cambridge, Massachusetts.

Whereas, the said Bell has invented certain new and useful methods of and apparatus for telegraphing, for which he has applied for letters Patent of the U. S., and is about to apply for other patents in the U. S., and has assigned all his right, title and interest in and to said inventions or improvements to the said Bell, Sanders and Hubbard, parties to this agreement, and has agreed to assign to said parties all his right, title and interest in and to any further improvements he may make in perfecting said inventions or improvements. Now, therefore, the said Sanders and Hubbard do hereby severally agree that they will each contribute one half part of all expenses incurred in taking out the patents for said inventions or improvements, and of any interference or interferences that may be had, as well as the necessary expenses that may be incurred in perfecting said inventions.

And it is further agreed between the parties hereto that if said inventions should prove to be of value that the said parties shall transfer all their rights to a company to be organized for the purpose of more easily managing and controlling said patents.

The stock that shall be issued for said patents to belong to said several parties, according to their respective interest therein, — namely, one third each.

This agreement shall be binding upon our heirs and legal representatives.

A. GRAHAM BELL.
THOMAS SANDERS.
GARDINER G. HUBBARD."

Cross-Int. 483. Did the experiments with the manometric capsule of Koenig, and the phonautograph, referred to in your answer to Question 30, demonstrate the fact that the shapes of vibrations obtained by the phonautograph which you used were not exact copies of the vibration of its membrane, but at best mere approximations?

Ans. No. I do not know that they demonstrated that. I sang the same vowels, in the same way, into the mouth-piece of the manometric capsule and into the cone of the phonautograph, and compared the tracings of the phonautograph with the form of the flame undulations visible in the mirror of the manometric capsule. The forms of the vibrations obtained in these two ways were not exactly identical, and I speculated as to the cause of the difference. The hypothesis that was in my mind was, that the true form of vibration characteristic of the sounds of speech had been distorted in

the phonautograph by the instrumentalities employed. This led me to make experiments in the improvement of the apparatus. It was simply an idea that was in my mind in the nature of a hypothesis, and may, or may not, have been true.

Cross-Int. 484. You say in answer to Question 32, that Dr. Blake suggested that instead of trying to make a phonautograph modelled after the pattern of the human ear, you should attempt the use of a human ear itself, taken from a dead subject, as a phonautograph. Was this suggestion original with Dr. Blake, or had the thing been done before?

Ans. I don't know. I think it was original with Dr. Blake.

Cross-Int. 485. Referring to Answer 33: you say that the apparatus shown in Fig. 15* of your preliminary statement in the *Harmonic Telegraph Interferences* was devised in the summer of 1874. Who first constructed an apparatus similar to Fig. 15, or made a model of it?

Ans. I cannot be quite certain whether a model exactly like Fig. 15 has ever been constructed, but I am inclined to think that I did have a pair of steel reeds attached to the poles of a permanent magnet in the way shown in that figure, at some period long after the date of conception — 1874 — but my memory is too vague to be relied upon without some contemporary evidence. It may be that no model exactly like Fig. 15 was ever made, but I cannot assert this positively.

Cross-Int. 486. Have you any definite recollection of the use by yourself of an apparatus similar to that shown in Fig. 15, or of its use by others?

Ans. Oh, yes. I have a definite recollection of the use by myself of apparatus operating substantially in the manner shown in Fig. 15, though the apparatus used was somewhat different in construction. My recollection is confirmed by a contemporaneous record in the shape of a letter to Mr. Hubbard, dated June 28, 1875, which has been quoted in my answer to Interrogatory 73 of the present deposition. The experiment was made on the evening of June 28, 1875 — the same day the letter was written. The form of apparatus employed was substantially similar to that shown in

* See page 21.

Fig. 5 of my patent of March 7, 1876, No. 174,465; but the steel reed which was used as the transmitter was arranged in a bed, as shown at A, in Fig. 15 of my preliminary statement, so that it could be set mechanically in vibration by wind, like an organ reed. The arrangement of circuit was similar to that shown in Fig. 5 of my patent No. 174,465, but the battery was omitted from the circuit. Under these circumstances the mechanical vibration of the transmitting reed, when blown by wind, occasioned so perceptible a sound from the receiving reed that I found it quite unnecessary to place my ear against the instrument. The vibration of the receiving reed was so great as to be perfectly perceptible to the eye as well as to the senses of touch and hearing.

Cross-Int. 487. The apparatus shown in Fig. 15, as I understand it, translates mechanical force into electrical energy; and then again, electrical energy into mechanical force. Can you state exactly, or approximately, the amount of force that is lost in this translation or operation?

Ans. I do not pretend to be an expert, and cannot, I think, venture to express an opinion upon the subject.

Cross-Int. 488. Is your acquaintance with the electrical and mechanical operation of the apparatus illustrated in Fig. 5 of your patent No. 174,465, sufficient to enable you to answer the same question in relation to that apparatus?

Ans. I don't think it is.

Cross-Int. 489. It is a fact, is it not, that on account of loss of power or force, the armature of the receiving instrument of Fig. 5 will not vibrate with the same amplitude as the armature of the transmitting instrument?

Ans. I cannot say; but should think it would depend upon circumstances. The reed of the receiver has a tendency to vibrate at a definite rate—like a child's swing, only with much greater rapidity—and a succession of very slight impulses may cause it to vibrate with very great amplitude if the impulses are properly timed to the movements of the reed; just as a child's swing may be set into full vibration by a series of very slight impulses from the hand, if these are properly timed to the movements of the swing, so that each push comes during the forward movement alone.

Cross-Int. 490. In my last question I intended that you should understand that the operation of the apparatus shown in Fig. 5 was the same as that stated in your patent. Please answer the question with this understanding.

Ans. My answer is the same. I cannot tell what the absolute amplitude of vibration of the receiving reed will be relatively to any given vibration of the transmitting reed. But whatever absolute relation there may be between the two, it is obvious that if we increase the amplitude of vibration of the transmitting reed, then the amplitude of vibration of the receiving reed will also be correspondingly increased; and if we diminish the former, the latter will also be diminished in like manner.

I may state the matter in another way: The reed of the transmitter in vibrating produces a musical tone of a certain definite pitch, and the reed of the receiver produces a tone of similar pitch. Now, if you set the reed of the transmitter (say *c*, Fig. 5, of my patent) mechanically into vibration, so as to produce its musical tone, electrical undulations will thereby be caused on the circuit *g b e f g*, and the reed *h* of the receiver will be thrown into vibration by the varying attraction of its electro-magnet *f*, so as to produce a musical tone of similar pitch to that occasioned by the vibration of the transmitting reed *c*. Now I do not mean to say how loud the tone produced by the receiving reed *h* may be relatively to that produced by the transmitting reed *c*. I think it depends upon circumstances. But what I do mean to say is, that if the amplitude of vibration of the transmitting reed *c* be increased so that the tone produced by it becomes louder, then the amplitude of vibration of the receiving reed *h* will also be increased, and its tone will become correspondingly louder. The converse also is true; so that variations in the loudness of the tone produced by *c* will cause corresponding variations in the loudness of the tone from *h*. This statement is based not simply upon theoretical considerations but upon actual experiences with apparatus substantially similar to that shown in Fig. 5.

Cross-Int. 491. The apparatus shown in Fig. 7 of your patent of March 7, 1876, No. 174,465, when operated according to the descriptive language of the specification, as I understand it, translates mechanical force into electrical energy; and then again, electrical

energy into mechanical force. Having reference to what you have testified on your direct examination concerning the currents produced by instruments employed by you, I will ask you whether your acquaintance with the electrical and mechanical operation of the apparatus shown in Fig. 7 is sufficient to enable you to state exactly or approximately the amount of force that is lost in this translation or operation.

Ans. No. My knowledge of electrical and mechanical matters is not sufficient to enable me to state either exactly or approximately what amount of force is lost in the operation of the apparatus shown in Fig. 7. I have no doubt that there is considerable loss, for the sound audible from L is not nearly so loud as the sound uttered into A.

Cross-Int. 492. I gather from your last answer, that the amplitude of the vibrations of the stretched membrane of the instrument L is less than that of the stretched membrane of the instrument A. Is that conclusion correct?

Ans. I am inclined to think so.

Cross-Int. 493. In the letter referred to in Cross-interrogatory 482 and your answer thereto, the following language is used:

"Another fortunate circumstance was this. That the very Examiner into whose hands this will come happened to be in Mr. Pollok's office one day when I called, so that I had a long interview with him, in which I explained everything to him, and I can't help thinking that he must have been convinced of my independent conception of the whole thing."

Who was this examiner with whom you had the long interview?

Ans. I presume that it must have been Mr. Wilber; but I cannot tell from my own recollection alone. I had forgotten that I ever had any such interview until my memory was refreshed by reading this letter.

Cross-Int. 494. You speak in the letter of another examiner in the Patent Office, who was a deaf-mute; who was that?

Ans. Mr. Parkinson.

Cross-Int. 495. Who first made and used an apparatus similar to that shown in Fig. 16* of your preliminary statement in the *Harmonic Telegraph Interferences*, or who first made a model thereof?

* See page 35.

Ans. I don't think that such an apparatus has ever been made or used, or a model made of it — at least, so far as I know.

Cross-Int. 496. Then I suppose you do not know whether or not such an apparatus as that shown in Fig. 16 is capable of transmitting articulate speech from a speaker to a listener?

Ans. Not from actual experiment. But I think we are entitled to consider that it is, from theoretical considerations.

Cross-Int. 497. Please carry your answer to the last question a little farther, and state why, from theoretical considerations, we are entitled to think the apparatus shown in Fig. 16 is capable of transmitting speech from a speaker to a listener.

Ans. Because we know that such an apparatus should be capable of transmitting simultaneously musical tones differing in loudness from one another, so that the receiving instrument should reproduce the tones without changing their relative intensity or loudness.

Cross-Int. 498. In your answer to Question 34, you use the following language :

“In this way I realized, in the summer of 1874, the conception of the speaking telephone, and the apparatus shown in Fig. 16 is the first form of speaking telephone that occurred to my mind.”

In view of this statement, will you please explain why it is that no apparatus similar to Fig. 16 has ever been constructed or used, from the summer of 1874, down to the present day?

Ans. In the first place, the apparatus shown in Fig. 16 was so changed and simplified in the summer of 1874, that it became unnecessary even to attempt the construction of the harp instrument of Fig. 16 for the purpose of transmitting speech. In the second place, it seemed probable that any harp apparatus we could construct like that shown in Fig. 16 would only approximately reproduce speech-sounds; for it seemed impracticable, as a matter of fact, to construct an apparatus with the multitudinous reeds that theory required. I looked upon Fig. 16 as a theoretical, rather than a practical, speaking telephone.

Cross-Int. 499. I understand you to say in your answer to Question 39 that you alluded in the specification of your application of February 25, 1875, to the receiving instrument of Reis's telephone.

To what particular form of the Reis receiving instruments do you refer in this answer?

Ans. I refer to the form of Reis receiving instrument shown in the so-called Reis publications entitled "No. 26. — Reis's Circular of August, 1863,"* in evidence in this case.

Cross-Int. 500. Is that the same receiver to which you refer in the next succeeding answer, to wit, that to Interrogatory 40?

Ans. Substantially the same, excepting that the coil of the instrument shown me at the Institute of Technology was larger, and it did not have, so far as I remember, the adjuncts of the telegraph-key, etc.

Cross-Int. 501. In the letter quoted in your answer to Question 49, you say that you told Professor Henry that on passing an intermittent current of electricity through an empty helix of insulated copper wire, a noise could be heard proceeding from the copper wire similar to that heard from the telephone. I suppose from this that you had experimented enough with the Reis telephone to recollect the kind of noise made by it. Am I correct in this supposition?

Ans. No. I had not experimented with the Reis telephone at all, but on the 26th of November, 1874, I had produced sounds from the iron core of an electro-magnet by passing an interrupted current through the coil, the receiver employed operating in a very similar manner to that of the receiver of the Reis telephone. Very shortly after that date — November 26, 1874 — Professor Cross, or one of the professors of the Institute of Technology, told me that the noise was similar to that heard from the receiver of the Reis telephone. This led him to describe the Reis telephone to me, and to show me the receiver he had at the Institute of Technology. Having observed the sound produced from the core of an electro-magnet, I found that a similar sound could be perceived from the empty helix when the core was removed. At the time the letter of March 18, 1875, was written, I knew that I was not the first discoverer of the effect from the iron core, and credited it to Reis by my reference to his telephone.

Cross-Int. 502. Who was the first to discover that a sound would be produced from an empty helix when the core has been removed, as mentioned in your last answer?

* See page 51.

Ans. I am not sure at the present moment. The discovery was original with myself, but I am inclined to think that the effect had been previously noticed by De la Rive.

Cross-Int. 503. Please give your reasons for your last answer.

Ans. I have read a work upon electricity by De la Rive, and I have a recollection of some chapter in his book being devoted to a description of experiments relating to the production of sound by magnetization. If I am not mistaken, he speaks in that chapter of having obtained sounds from an empty helix of copper wire. I may, perhaps, be wrong in my reference, but I feel pretty sure that I found out, long after my independent discovery of the effect, that it had been previously noted by others.

I find, on reference to my testimony in the *Dowl* suit, that I was asked about this by Mr. Causten Browne, on cross-examination. The question and answer were as follows:

“*Cross-Int.* 248 (*de bene*). In your letter of March 18, 1875, put in evidence with your fifty-seventh answer, you speak of telling Professor Henry ‘that on passing a current of intermittent electricity through an empty helix of insulated copper wire, a noise could be heard proceeding from the coil similar to that heard proceeding from the telephone.’ Did you never afterwards learn that that fact had been observed already by some one before you?”

Ans. I did. I found that this fact had been discovered by De la Rive. It is referred to in a paper by him in the *Annales de Chimie et de Physique*, Third Series, Volume XVI., page 104.”

This shows that in the first part of the present answer I was mistaken as to the reference, but not as to the man.

Cross-Int. 504. Is the work, *Annales de Chimie et de Physique*, referred to in your last answer, cited in your lecture before the American Academy, which has been heretofore referred to?

Ans. In my American Academy paper I gave a number of references to the writings of De la Rive, but that particular article does not seem to be referred to.

Cross-Int. 505. In your interview with Professor Henry, referred to in your letter to your parents, did he call your attention to any of the Reis publications?

Ans. I do not think he did.

Cross-Int. 506. In your answer to Question 56 you quoted an

extract from her father's journal, given to you by the daughter of Professor Henry. If the words quoted do not comprise all of the extract, will you please give it in full?

Ans. The following is the full extract found in Professor Henry's journal, under the date of March 2, 1875, sent to me by his daughter :

"Experiments with Mr. A. Graham Bell of Boston on the sound made by an interrupted current passing through a cylindrical coil of wire without an iron core. The sound appeared to be the conduction through the wire of the break-circuit apparatus. It is possible that this is not the case. Try the effect with an induced coil inside the original."

Cross-Int. 507. In your answer to Question 60 you refer to Mr. Frank L. Pope. Is he the same Frank L. Pope who has testified as an expert in behalf of the American Bell Telephone Company?

Ans. On consulting the record in the suit of *Bell Telephone Co.* et al. v. *Peter A. Dowd*, I find that Mr. Frank L. Pope testified on behalf of the defendant in that suit, May 9, 1879, and following days; and on consulting the record in the suit of *American Bell Telephone Co.* et al. v. *The People's Telephone Co.* et al., I find he testified on behalf of the complainant in that suit, March 29, 1883, and following days. I presume that is the same Mr. Frank L. Pope to whom I refer in my answer to Interrogatory 60.

Cross-Int. 508. In a letter quoted in answer to the sixty-fourth question you used the following language :

"The two patents for the transmission of musical notes are not decided yet. I can't understand why the interference should not have been declared before this."

To what interference did you refer?

Ans. By reference to the certified copy of the file-wrapper and contents of my application of February 25, 1875, I find the following letter from the Examiner which explains the matter :

Copy sent)	EXAMINER'S ROOM NO. 118,
Mar. 30')	U. S. PATENT OFFICE,
I. R. A.)	WASHINGTON, D. C., March 30" — 1875.

A. G. BELL,

Care Pollok and Bailey, Present.

Transmitting Telegraphic Messages. 75/2. Feby. 25, 1875.

Applicant is notified that there are applications on file interfering

with this, and that as soon as certain necessary amendments are made in such other cases, the preliminary interference will be formally declared. The interfering applicants have been requested to take speedy action in view of the necessity for interference.

Z. F. WILBER,
Examiner.

And by reference to the certified copy of the file-wrapper and contents of my application of March 10, 1875, I find the following letter :

Copy sent	}	EXAMINER'S ROOM NO. 118,
Mar. 30,		U. S. PATENT OFFICE,
S. R. A.		WASHINGTON, D. C., March 30th, 1875.

A. G. BELL,
Care Pollok and Bailey, Present.

Transmitting and Receiving Telegraphic Messages. 76/22.
March 10th, 1875.

The letter of even date herewith in applicant's case, filed February 25th, 1875, applies to this case.

Z. F. WILBER,
Examiner.

Cross-Int. 509. In your letter to Mr. Hubbard, referred to in your answer to Question 79, you speak of a French work containing a description of Bonelli's telegraph. What work was this ?

Ans. I do not remember at the present moment. I am inclined to think it was either De la Rive's work on electricity, or a work by Comte Du Moncel.

Cross-Int. 510. Who made the drawings referred to in your answer to Question 82 ; and when were they made ?

Ans. I produced them during my cross-examination by Lysander Hill, Esq., in the case of *American Bell Telephone Co. et al. v. The People's Telephone Co. et al.*, on the 20th of February, 1883. I cannot pretend to say now who it was that made the drawings originally.

Cross-Int. 511. I understand from your last answer, that the 20th of February, 1883, is the earliest date that you can assign for these drawings. Is that so ?

Ans. I think so, for these particular drawings ; but others substantially similar were introduced in evidence in the *Dowd* suit in 1879. I may add, that I remember that the sectional drawings con-

tained in my answer to Interrogatory 82, and formally produced in evidence on the twentieth day of February, 1883, were made to scale from the remains of the original membrane telephones used in June and July, 1875, which are still in existence.

Cross-Int. 512. Having reference to your answer to Question 84: Will you please describe particularly the relative positions of the transmitting and receiving instruments, their distance apart, and also the situations of the rooms in the building in which the instruments were placed?

Ans. In the upper story of Mr. Williams's building there was a little room in which my apparatus was kept — a sort of store-room, if I remember rightly. My impression is that this room was partitioned off from a larger room, forming a sort of store-room contained within a larger room. At all events, there were two rooms on this upper floor, with a communicating door, which either had a glass window in it or a glass window near it, so that Mr. Watson and I could see one another when we were making experiments in the adjoining rooms. In the experiment referred to, one of the membrane telephones was in the little room where I kept my apparatus; the other was in one of the lower rooms in the building; I do not remember which it was, probably in the lowest room occupied by Mr. Williams's establishment, so as to be as far away as possible from the other instrument. The two instruments were connected in a metallic circuit with insulated copper wire. I am sure I cannot tell the distance, excepting that the two instruments were probably as far away from one another as we could get them in Mr. Williams's building.

Cross-Int. 513. You say the instruments were probably as far away as you could get them. Is this merely a surmise made by you at the present time, or have you any definite recollection upon the subject?

Ans. My recollection simply is that one instrument was upstairs and the other downstairs, the two being out of ear-shot of one another.

Cross-Int. 514. Please state a little more definitely what you mean by the words "out of ear-shot of one another," as I understand the term to be a relative one, which might apply to a short distance

or to many miles, according to the circumstances of the particular case.

Ans. I mean that the unassisted ear of the listener could not perceive the voice of the speaker. It may perhaps be that we did not actually get out of ear-shot of one another, but that was our aim and intention, and we tried to have the instruments far enough away from one another to prevent the possibility of sounds being transmitted through the air.

Cross-Int. 515. How many stories had this house of Mr. Williams in which these experiments were conducted?

Ans. I am afraid I cannot say from memory ; but the building is still standing, though used for other purposes. I remember I had to go up a flight of stairs to come to Mr. Williams's office. Then there was a workshop over that, and, I think, but am not quite certain, that there was still another workshop above that. Our experimental room was on the top floor. I cannot pretend to be definite, and simply give you my vague recollection for what it is worth.

Cross-Int. 516. What is the present street and number of Williams's house?

Ans. Mr. Williams's establishment used to be numbered No. 109 Court Street. I do not know that there has been any change in the number since then, though there may have been.

Cross-Int. 517. What kind of business was carried on in this establishment of Williams's referred to in your last answer?

Ans. The manufacture of telegraphic and electrical apparatus.

Cross-Int. 518. I suppose machinery, of course, was used. On what floor was the machinery located?

Ans. I think on the floor above Mr. Williams's office, and perhaps on another floor above that.

Cross-Int. 519. Mr. Williams's office, I believe, was on the second floor; the machinery, therefore, I take it, was located on the third floor. Is that so?

Ans. Yes. I think so. That is, if you call the ground floor the "first floor"; but I only speak from vague recollection.

Cross-Int. 520. What was the first or ground floor used for?

Ans. I don't remember now. I do not think it was occupied by Mr. Williams at all.

Cross-Int. 521. During what hours of the day was machinery running — if you recollect — in this establishment of Mr. Williams's?

Ans. I cannot answer positively. I think till about six o'clock in the evening.

Cross-Int. 522. During what hours of the day were your experiments carried on at Mr. Williams's establishment? I refer more particularly to your general business hours.

Ans. I do not remember at the present time. My recollection is that I had a particular reception hour at my rooms at the Boston University, during which it was understood I would always be there; and that I would run down to Mr. Williams's before or after this hour, according to my freedom from professional work. The time is so long ago, however, that I do not feel confidence in the accuracy of my reply. I remember that on some occasions I kept Mr. Watson overtime, in order to try experiments after the workmen had gone away.

Cross-Int. 523. Did you have facilities at Mr. Williams's establishment for conducting experiments after dark as well as during daytime?

Ans. I do not think so. My recollection is that the whole building was locked up after about six o'clock in the evening, and left in charge of a janitor, and that it was very inconvenient to have any experiments made there after the workmen left and the closing of the building.

Cross-Int. 524. In your letter to Mr. Hubbard, contained in your answer to Question 79, you use the following expression: "The experiment to which I alluded when I saw you last promises to be a grand success." What was this experiment to which you referred, and when did you last see Mr. Hubbard prior to July 1, 1875?

Ans. The experiment to which I alluded was the transmission of articulate speech electrically, by means of membrane telephones substantially similar to those shown in my patent of March 7, 1876, and illustrated in Fig. 7 of that patent. I do not know when I last saw Mr. Hubbard prior to July 1, 1875. In a letter to him, dated June 2, 1875, I said: "I shall call upon you to-morrow (Wednesday) evening," which seems to indicate that he either was in Cambridge

on the 3d of June, or was expected to be there at that time, and I may have seen him then. In another letter, written by me to Mr. Hubbard on the 28th of June, 1875, I say: "Shall call in the evening and report progress." This seems to indicate that he was in Cambridge on the 28th of June, and that I probably saw him that evening. I cannot say positively when I last saw Mr. Hubbard prior to July 1, 1875.

Cross-Int. 525. When did you first construct, or cause to be constructed, an instrument exactly similar in all respects to that shown in Fig. 7 of your patent of March 7, 1876, No. 174,465?

Ans. I never constructed an instrument precisely similar in all respects to that mentioned, but, on the 2d of June, 1875, I ordered the construction of two instruments substantially similar to those shown in Fig. 7 of my patent of March 7, 1876, and such instruments were actually constructed and operated in June and July, 1875. That date—June 2, 1875—is impressed upon my memory by the fact of my having made, upon that day, the experiment and discovery I have described in answer to Interrogatory 68. On that day Mr. Watson had plucked with his finger the tuned reed of a multiple-telegraph receiver like that shown in Fig. 5 of my patent of March 7, 1876, and I observed that the reed of another receiver of similar pitch was thrown into vibration at every pluck. The arrangement was similar to that shown in Fig. 5 of my patent, excepting that there was no battery upon the circuit. This experiment made a very great impression upon my mind at the time, as it instantly removed the impression I had retained since the summer of 1874, that magneto-electric currents generated by the sonorous vibration of an armature in front of the pole of its electro-magnet would be too feeble to be practically used for the purposes of multiple telegraphy or speech-transmission. The discovery of June 2, 1875, dispelled from my mind in a moment the idea that the membrane speaking telephones devised in the summer of 1874 (which were substantially similar to those shown in Fig. 7 of my patent of March 7, 1876, excepting that I did not propose to employ a battery) were more theoretical than practical speaking telephones, on account of the supposed feebleness of the sonorous effects produced at the receiving end. The discovery of June 2, 1875, led me at once to

the belief that the membrane speaking telephones devised in the summer of 1874 would prove practically operative speaking telephones, and my recollection is very clear that I instantly gave instructions to have such instruments made. I know that the construction of these instruments was ordered on the same day as the discovery referred to above, and my memory retains the date as June 2, 1875. This date is confirmed by a contemporaneous record in the shape of a letter that I wrote to Mr. Hubbard on the 2d of June, 1875. My own unaided recollection would lead me to say that the membrane telephones which were ordered on the 2d of June, 1875, were made and operated within a few days after that date, but I am satisfied, from a letter that I wrote to Mr. Hubbard on July 1, 1875, that only one of the membrane telephones had been constructed previously to July 1, and that the other membrane telephone was not completed until the 2d of July, 1875.

Cross-Int. 526. You mean by your last answer, do you, that down to the present day — June 13, 1892 — you never constructed, or caused to be constructed, an instrument precisely similar to either of those instruments illustrated in Fig. 7 of your patent of March 7, 1876?

Ans. In June and July, 1875, Mr. Watson constructed for me instruments substantially similar to those referred to. I have never myself constructed, or caused to be constructed, an instrument precisely similar to either of those instruments illustrated in Fig. 7 of my patent of March 7, 1876—I mean precisely similar in all respects, although I know that this has been done by others since the date of my patent. The instruments constructed for me in June and July, 1875, were precisely similar in material respects, though differing slightly in details of construction.

Cross-Int. 527. In order that I may understand what you mean by the words “substantially similar” and the expression “material respects,” in your last answer, will you please point out all the features of similarity and all the features of dissimilarity between the instruments shown in Fig. 7 of your patent of March 7, 1876, and the instruments constructed for you by Mr. Watson in June and July, 1875; and also designate those differences in the details of construction which you have referred to in your last answer?

Ans. The instruments constructed for me by Mr. Watson in June and July, 1875, have been described in detail and illustrated by drawings in my answer to Interrogatory 82. A comparison of those drawings with the drawings in Fig. 7 of my patent of March 7, 1876, will show precisely all the features of similarity and all the features of dissimilarity, and also all differences in details of construction. In order that you may understand what I mean by "substantially similar" and "material respects," I may say that my patent of March 7, 1876, describes the apparatus shown in Fig. 7 as follows:

"The armature *c*, Fig. 7, is fastened loosely by one extremity to the uncovered leg *d* of the electro-magnet *b*, and its other extremity is attached to the centre of a stretched membrane, *a*. A cone, *A*, is used to converge sound-vibrations upon the membrane. When a sound is uttered in the cone the membrane *a* is set in vibration, the armature *c* is forced to partake of the motion, and thus electrical undulations are created upon the circuit *E b e f g*. These undulations are similar in form to the air-vibrations caused by the sound — that is, they are represented graphically by similar curves.

The undulatory current passing through the electro-magnet *f* influences its armature *h* to copy the motion of the armature *c*. A similar sound to that uttered into *A* is then heard to proceed from *L*."

Now this language would apply equally well to the instruments made in June and July, 1875, and described in detail in my answer to Interrogatory 82. These instruments were, therefore, substantially similar to those of my patent in those respects that are described as material in the patent itself.

In regard to dissimilarity, I may say that the instruments constructed in June and July, 1875, did not have a cone *A* to converge sound-vibrations upon the membrane (see Fig. 7 of my patent) nor a hearing-tube *L* to aid the ear in perceiving the sounds emitted by the receiving instrument. These appear to me to be the chief points of similarity and dissimilarity.

Cross-Int. 528. In the instrument described in detail in your answer to direct Interrogatory 82 and referred to by you in your last answer, I find a device designated as "a straining-ring *R* having three metallic projections." Do you find any such device described, illustrated or referred to in your patent of March 7, 1876, No. 174,465; or do you find in that patent any means whatever for adjusting the position of the membrane?

Ans. The patent describes the membrane α , Fig. 7, as a "stretched membrane." The means whereby it is stretched is immaterial, and is not specially shown in the drawing. Any of the ordinary or usual means of stretching membranes is supposed to be sufficient. Fig. 7 is only a diagram.

Cross-Int. 529. I find also in the instruments illustrated and described in detail in your answer to Question 82 devices which are referred to by you in that answer as follows:

"Attached to the board F are side pieces U, U, carrying a cross-bar B, which is retained in position in the slotted ends of the side pieces by screws, J, J. The cross-bar B supports an electro-magnet, H E, which is attached to the cross-bar by a screw and nut at N."

Do you find any such devices referred to, described or illustrated in your patent No. 174,465?

Ans. Fig. 7, as I have said, is only a diagram. For example, the armature c in Fig. 7 is assumed to be within the field of attraction of its electro-magnet b , and at such distance from the pole as is usual in the construction of electro-magnetic apparatus. The exact means whereby this may be effected is immaterial, and not specially shown in the drawing; but is assumed to be any of the well-known means employed in the construction of ordinary electro-magnetic apparatus.

Cross-Int. 530. In your answer to Question 82, you use the following language:

"If I remember rightly, we did not at first adjust the electro-magnet, in the earlier instrument, by changing the position of the cross-bar, but we did do so by means of the screw and nut shown at N. By unscrewing the nut a little, we could cause the electro-magnet to approach its armature more closely and retain this position by means of washers or thin pieces of metal placed between the cross-bar and the heel-piece of the electro-magnet."

Do you find in your patent No. 174,465, any such devices described, illustrated or referred to; or do you find in such patent any means for adjusting the distance of the electro-magnet from its armature?

Ans. Fig. 7, as I have said before, is a mere diagram. The means whereby the armature and electro-magnet are retained in position with respect to one another is not specially shown. It is

assumed that such means would be employed as is usual in the construction of ordinary electro-magnetic apparatus. If, by "adjusting the distance of the electro-magnet from its armature," you mean providing a means of *changing* the distance of the electro-magnet from its armature, such a device is immaterial, as it is sufficient to fix the electro-magnet and armature in position relatively to one another.

Cross-Int. 531. I understand you to say in your last answer that devices for changing the distance of the electro-magnet from its armature are immaterial. If this is so, why have you taken pains to describe and claim such means in your patent No. 186,787? I refer particularly to Figs. 2 and 3 of the drawing of said patent, and to the fourth claim, which is as follows:

"4. In combination with a plate and electro-magnet, as before claimed, the means herein described, or their mechanical equivalents, of adjusting the relative position of the two so that, without touching, they may be set as closely together as possible."

Ans. In my last preceding answer I said that devices for changing the distance of the electro-magnet from its armature are immaterial, as it is sufficient to fix the electro-magnet and armature in position relatively to one another. In an instrument like that shown in my patent of January 30, 1877, No. 186,787, and illustrated in Figs. 2 and 3, where the electro-magnet and armature are not immovably fixed with respect to one another, a means of adjustment may be advisable; and it seemed to me that the means shown were convenient and practicable, and therefore, worthy of being claimed in such a combination as that described.

Cross-Int. 532. In the iron-box receiver used by you at the Centennial, were means provided by you for changing the distance between the armature and the electro-magnet?

Ans. The diaphragm armature was in contact with one of the poles of the electro-magnet, and the other pole was adjustable, as shown in the sectional drawing contained in my answer to Interrogatory 122.

Cross-Int. 533. Was the mode of adjustment referred to by you in your last answer devised by you or some one else? I refer, of course, to the mode of adjustment shown in the iron-box receiver.

Ans. I do not know. My recollection is that I gave Mr. Wat-

son instructions to make the core of the iron-box receiver adjustable up and down by means of a screw, and that the apparatus, as illustrated in the drawing given in my answer to Interrogatory 122, was the result. The adjusting device itself was not new, although its combination as part of a receiving telephone was new.

Cross-Int. 534. I wish you would, as far as your memory enables you to do so, give a complete history of the iron-box receiving instrument to which you have referred in your last answer; stating particularly how it happened to be constructed, from what material it was made, and who constructed the various parts of it.

Ans. The idea of such a receiver originated in my mind, I think, in March, 1876. In that month I had heard articulate speech produced by a tuned-reed receiver like that shown in Fig. 5 of my patent of March 7, 1876, when the reed was damped by close contact with my ear. The tendency of the reed to vibrate at a definite rate of its own was a disadvantage in using the tuned reed as a receiver for speech, and it occurred to me that we could reduce its tendency to a definite rate of vibration, by clamping the reed firmly at both ends, and subjecting the centre of the reed to the attraction of an electro-magnetic core. To this end I devised, in March, 1876, a new form of receiver which consisted of an electro-magnet with three parallel legs. A coil was to be placed around the centre leg, and a strip of steel was to form a bridge passing over the centre pole without touching it, and in magnetical contact at either end with the two uncovered poles of the electro-magnet. The ear was to be pressed against the centre of the steel bridge. One great advantage that occurred to me in this connection, was that the opposite poles of the electro-magnet would be very close together; the end of the covered leg constituting one pole, and the centre of the steel armature the other. In considering the operation of such an apparatus, it occurred to me that a still more powerful magnetic condition could be caused in the centre of the steel armature by making the steel bridge in the shape of a circular disk of thin steel, and placing its edge in contact with a series of uncovered legs arranged in a circle around the covered leg. It also occurred to me that an iron box or a tubular magnet would have the same effect as the circle of uncovered legs. I remember very distinctly that the idea of the iron-box receiver

was developed from the tuned-reed receiver shown in Fig. 5 of my patent of March 7, 1876, through three stages: 1. A receiver with a three-legged electro-magnet. 2. An electro-magnet with a central covered leg and a circle of uncovered legs. 3. An electro-magnet with a central covered leg and a tubular iron box surrounding it. I remember going to Mr. Williams's in March, 1876, to have an improved receiver made. I do not now remember which one of the three improved forms I had then in mind. I am inclined to think it was the three-legged form. At all events, in looking over a lot of odds and ends in Mr. Williams's workshop, I saw some old apparatus there with a tubular magnet, and it immediately occurred to me that that iron box was just the thing I wanted. I do not now remember whether I had arrived at the conception of a ring of uncovered poles, and its equivalent, a tubular magnet, before going to Mr. Williams's upon that occasion, or whether it was the sight of this old instrument that suggested these forms to my mind, but I am inclined to think that I had arrived at the idea of the iron-box receiver before. At all events, I do remember that the moment I saw this old apparatus I thought that the tubular magnet was just the thing I wanted, and that it could be converted into the iron-box receiver, the conception of which had either arisen in my mind before, or came into my mind at that moment. I therefore instructed Mr. Watson to take the iron tube from the apparatus. He was instructed to provide it with a central core adjustable up and down, as shown in the drawing in my answer to Interrogatory 122, and with a flat disk or diaphragm of thin steel which would fit on the top of the box like a lid, making magnetical contact with the circular rim of the tubular magnet, while the central core was to be adjusted so as to come very near the centre of the steel diaphragm without touching it. I am inclined to think that Mr. Watson also provided the coil which filled the interior of the iron box, but am not quite sure; it may possibly have been in the magnet in its original condition, but I am not quite certain.

Cross-Int. 535. Please describe the tubular magnet referred to in your last answer, as it was when you first saw it in Mr. Williams's shop, making, if you choose, any illustrations that you desire.

Ans. I do not remember the apparatus with sufficient distinct-

ness. I only remember that there was some old, rusty apparatus among the odds and ends in Mr. Williams's shop. What the nature of it was, or what its shape or condition, I do not now remember. The thing that interested me about it was that it contained a tubular magnet, and I thought that the iron tube could be used in the construction of the form of receiving telephone now known as the iron-box receiver, and thus save the trouble and expense of making such a tube. The exact nature of the tube can be seen from the Centennial Iron-Box Receiver, which is still in existence. The iron box of that receiver was originally a part of the old apparatus referred to; all the rest of it was made by Mr. Watson or under his direction, so far as I know.

Cross-Int. 536. When did you first see a magnet of the type known as the tubular electro-magnet?

Ans. I think I first saw such a magnet in the old apparatus referred to, in Mr. Williams's shop, in March, 1876, although I was familiar with the form from drawings and printed descriptions as early as July, 1875.

Cross-Int. 537. What were these drawings and printed descriptions to which you refer in your last answer?

Ans. I refer to a work upon electricity, by the Comte Du Moncel, which I was studying in July, 1875. I fix this date, as I gave a quotation from this work to Mr. Hubbard, in a letter I wrote him, on the 7th of July, 1875, and which I read in my answer to Interrogatory 88.

Cross-Int. 538. Did the tubular magnet to which you refer, described in the book of Du Moncel, consist of a core, a cylindrical shell surrounding and connected to one end of the core, and a coil between the core and the exterior shell, and a disk armature resting upon the cylindrical shell; the core forming the one pole of the magnet, and the cylindrical shell the other?

Ans. If I remember rightly, the tubular magnet described by the Comte Du Moncel consisted of a core, a cylindrical shell surrounding and connected to one end of the core, a coil between the core and the exterior shell; the core forming one pole of the electro-magnet and the cylindrical shell the other. As I remember the drawing there was no disk armature, and the end of the central core was in

the same plane with the edge of the cylindrical shell without means of adjustment, so that an armature applied to the face of the tubular magnet would make contact with the end of the central core as well as with the end of the cylindrical shell.

Cross-Int. 539. You stated yesterday that you were familiar with the form of the tubular electro-magnet, from drawings and printed descriptions, as early as July, 1875, and that, as you remembered the drawings in Du Moncel's work, there was no disk armature. How was it with the printed description in Du Moncel's work? Was there any reference there to the disk armature of the tubular magnet?

Ans. The tubular magnet did not have a disk armature, nor was any reference made to such an armature in the body of the book, so far as I remember.

Cross-Int. 540. Du Moncel has, I believe, written a great deal upon the subject of electro-magnets. Will you please specify, as nearly as you can, to what particular work of his you refer in your answer to direct Question 88, which you referred to yesterday?

Ans. I think it was a work entitled *Exposé des Applications de l'Électricité*.

Cross-Int. 541. In the same letter referred to by you in your answer to direct Question 88, you illustrated a club-footed electro-magnet, and used the following language in regard to it:

"I think also that the effects are in some way dependent upon the peculiar form of electro-magnet employed. I hope to get some light on the subject from Moncel. He devotes several pages to the discussion of peculiarities observed in the one-legged or 'lame' magnet (*boiteux*) shown in his work as follows: "

And following this description is an illustration of two club-footed electro-magnets, the one having its armature apparently pivoted to the leg on which is the coil, and the other having its armature pivoted to the leg having no coil. These electro-magnets which are thus illustrated are in fact simple horseshoe electro-magnets having a coil upon the one leg thereof, and no coil upon the other leg thereof. That is so, is it not?

Ans. Substantially so, I think.

Cross-Int. 542. And each of the instruments shown in Fig. 5 of

your patent No. 174,465 is an electro-magnet having a coil upon the one leg thereof, and no coil upon the other leg thereof. That is so, is it not?

Ans. Such an electro-magnet forms a part of each instrument.

In my patent the instruments shown in Fig. 5 are described as follows :

"In illustration of the method of creating electrical undulations, I shall show and describe one form of apparatus for producing the effect. I prefer to employ for this purpose an electro-magnet, *A*, Fig. 5, having a coil upon only one of its legs, *b*. A steel-spring armature, *c*, is firmly clamped by one extremity to the uncovered leg *d* of the magnet, and its free end is allowed to project above the pole of the covered leg. The armature *c* can be set in vibration in a variety of ways, one of which is by wind, and, in vibrating, it produces a musical note of a certain definite pitch."

Cross-Int. 543. And the electro-magnet shown in either of the instruments illustrated in Fig. 7 of your patent No. 174,465 is a club-footed electro-magnet having a coil upon one leg thereof, and no coil upon the other leg thereof, and an armature hinged to the uncovered leg, as shown in the right-hand figure from Du Moncel, referred to in the letter mentioned in your eighty-eighth answer. That is so, is it not?

Ans. Such an electro-magnet forms a part of each of the instruments shown in Fig. 7 of my patent; but the armature in each case consists of a steel spring, like that shown in Fig. 5 of the patent, which is fastened loosely by one extremity to the uncovered leg of the electro-magnet, while its other extremity is attached to the centre of a stretched membrane.

Cross-Int. 544. Is there any advantage in winding the coil on one leg of the club-footed electro-magnet, as shown in Fig. 7 of your patent No. 174,465, instead of winding coils on both legs; and is it not a fact that you could not make as many turns for a given weight of copper wire, if you wound all the wire on one leg, as if you wound it on both legs?

Ans. My experiments seemed to indicate that for telephonic work it was advantageous to wind the coil on one leg, instead of winding coils on both legs in apparatus like that shown in Fig. 7 of my patent.

In regard to the second part of the question: It depends, of course, upon the size of the wire. You could get a greater number of turns upon the one leg alone, if you used very fine wire, than if you used coarser wire on both legs; but if you used the same size of wire in each instance, I presume your assumption would be correct.

Cross-Int. 545. Why was it advantageous in telephonic work, to wind the coil on one leg, instead of on both legs, of the electro-magnets used?

Ans. Comparative experiments seemed to indicate that this was advantageous; and besides, I had the idea that the magnetic condition of the iron core would be greater if the wire was all coiled up on the one leg, than if it was used to form two coils, one on each leg.

Cross-Int. 546. If the bar magnet described as F, in Figs. 2 and 3 of your patent No. 186,787, was bent in a horseshoe form — using the word “horseshoe form” in its generic sense as applied to electro-magnets — it would create such an electro-magnet as the club-footed electro-magnet shown in either of the instruments of Fig. 7 of your patent No. 174,465, would it not?

Ans. Yes, substantially.

Cross-Int. 547. In your answer to Cross-question 524 you say:

“In another letter written by me to Mr. Hubbard on the 28th of June, 1875, I say: ‘Shall call in the evening and report progress.’”

Has that letter been before referred to by you in your deposition in this cause?

Ans. Yes. I read the letter in my answer to Interrogatory 73.

Cross-Int. 548. In your answer to Question 528 you say:

“The patent describes the membrane *a*, Fig. 7, as a ‘stretched membrane.’ The means whereby it is stretched is immaterial, and is not specially shown in the drawing.”

In the membrane instruments used by you at the Centennial, were means provided for stretching the membranes?

Ans. Yes. Straining-rings were employed.

Cross-Int. 549. Did you ever construct or cause to be constructed a membrane telephone in which straining-rings or means for stretching the membrane were not used?

Ans. I do not think so. But I have known of membrane telephones constructed by others which had no straining-rings nor any means of changing the tension of the membrane after it was first stretched, and these telephones operated successfully.

Cross-Int. 550. When was it that the first telephone was constructed by others, which had no straining-ring or equivalent means for stretching the membrane?

Ans. I do not know; but it was subsequently to the issuance of my two patents No. 174,465 and No. 186,787. The membrane telephones to which I refer were precisely like the instruments shown in Fig. 7 of my patent of March 7, 1876, in all respects.

Cross-Int. 551. Was the instrument referred to by you in your last answer constructed for the purpose of being used in any litigation in which your patents were involved, or in connection with any litigation in which your patents were involved?

Ans. I believe they were constructed for the purpose of testing the point whether instruments precisely like those shown in Fig. 7 of my patent of March 7, 1876, in all respects, and without straining-rings or other means of adjusting the tension of the membrane, would talk and prove practically operative speaking telephones. They did talk, and were produced as evidence of the fact in some litigation in which my patents were involved.

Cross-Int. 552. Was the iron-box receiver which you instructed Mr. Watson to make, as stated in your answer to Cross-question 534, the first telephone instrument the plate armature of which was entirely constructed of metal?

Ans. It depends entirely upon what you mean by "plate armature." In tuned-reed receivers constructed by me in 1873 I used steel plates as armatures, and by pressing my ear into close contact with a plate armature of that description I could perceive musical tones produced by forced vibrations in the plate quite different in pitch from the musical tone produced by the normal vibration of the plate; and in March, 1876, I heard words and sentences from the plate armature of one of my tuned-reed receivers when pressed firmly against my ear. These experiments preceded the construction of the iron-box receiver.

Cross-Int. 553. The plate armature from which you heard words

and sentences, as testified in your last answer, was the same as the plate armature shown in either of the instruments of Fig. 5 of your patent No. 174,465, was it not?

Ans. Substantially the same, excepting that it operated in an entirely different manner. I pressed my ear firmly against the reed so as to prevent it from vibrating to produce its fundamental tone. By thus damping the free vibrations of the reed I was enabled to hear, as sound, forced vibrations that would not have been competent to produce any sensible vibration of the reed if it had been arranged as in Fig. 5, with its end free.

Cross-Int. 554. Has any attempt ever been made by any person at any time to use the steel-plate armature from which you say you heard words and sentences, or one similar to that, as a transmitter of articulate speech?

Ans. I do not think so.

Cross-Int. 555. You have referred to a tubular electro-magnet described in a work of Du Moncel, and also an instrument known as the iron-box receiver. As I understand your description, the only substantial differences between the iron-box receiver and the tubular electro-magnet referred to by Du Moncel were that in the latter the central core came in contact with the disk-armature plate, and that in the latter a steel plate armature was not provided. Is my understanding correct?

Ans. No. In the first place, there was no disk-armature plate at all in the tubular magnet shown by Du Moncel. 1. The central core of the tubular magnet shown by him was fixed, and not adjustable, and its end was flush with the edge of the tubular part. 2. Any armature, therefore, to be effective with such a magnet could not normally be in contact with either of the poles, — neither in contact with the central core nor with the circular edge of the tubular part, — otherwise the attraction of the electro-magnet could not move it, for if it was in contact with one of the poles it would also be in contact with the other, and no motion could result. 3. There was no armature shown in Du Moncel's drawing of the tubular magnet, and in the body of the work there seemed to be no reference to any other sort of armature than a thick mass of metal, not at all in the shape of a disk or diaphragm.

In the case of the iron-box receiver :

1. The central core was adjustable up and down, and its normal position was not flush with the circular edge of the tubular part, but was below that edge, so that an armature making contact with the circular rim would not touch the central core. 2. The armature rested normally upon the circular rim of the tubular magnet, and was permanently in magnetical contact with it, the centre of the armature not touching the central core. 3. The armature of the iron-box receiver was in the shape of a thin disk or diaphragm of metal. In the original instrument it was made of steel, but Tagger's iron was sometimes employed as the material.

These appear to me to be the chief points of difference between the two electro-magnets considered.

Cross-Int. 556. Would the differences which you have mentioned in your last answer prevent the tubular magnet of Du Moncel from being used as a receiver of articulate speech?

Ans. I think so.

Cross-Int. 557. Is your last answer based on any experiment which you have actually tried?

Ans. I have not made special experiments to test the point, for it seems obvious enough from the construction of the apparatus.

Cross-Int. 558. In your answer to Cross-question 545, you say that comparative experiments seemed to indicate that it was an advantage to wind the coil on one leg, and that you had an idea that the magnetic condition of the iron core would be greater if the wire was all coiled up on one leg than if it was used to form two coils, one on each leg. Did you afterwards ascertain that the idea that the magnetic condition of the iron core would be greater if the wire was all coiled up on the one leg thereof, than if it was used to form two coils, was a fallacy, or did your subsequent experiments confirm you in the correctness of the idea?

Ans. I understood that the point was one already settled and well-known in the condition of the art. That is, I understood that it was a settled point that the magnetic condition of the iron core would be greater if the wire was all coiled up on the one leg than if the same wire was used to form two coils, one on each leg. I could not tell, however, without experiment, whether such a condition

would be specially advantageous for the purposes of a speaking telephone. Comparative experiments made with tuned-reed receivers like those shown in Fig. 5 of my patent of March 7, 1876, with coils sometimes on one leg, sometimes on the other, and sometimes on both, seemed to indicate that for telephonic work there was an advantage in having the coil upon one leg of the electro-magnet as shown in my patent—at least that was my belief at the time the application was filed. I have seen no reason since then to change my views on these points.

Cross-Int. 559. Did you find in Du Moncel's work, to which you referred yesterday, and also in your letter to Mr. Hubbard, an account of the researches made by him as to the best position for placing the coil upon the iron core?

Ans. If I remember rightly, there was some discussion of the subject in the pages of Du Moncel's book.

Cross-Int. 560. When did you first commence the study of Du Moncel's work of which you have spoken?

Ans. I do not know, but from my letter to Mr. Hubbard of July 7, 1875, I find I was reading the book at that time.

Cross-Int. 561. I understood from your answer to Question 545 that you had an idea that the magnetic condition of the iron core would be greater if the wire was all coiled up on the one leg than if it was used to form two coils, one on each leg, and from a subsequent answer made this morning I got the idea that you deemed the coiling of the wire upon the one leg of a horseshoe magnet, instead of on each leg thereof, beneficial for telephonic work. Please state why such a mode of construction is particularly beneficial for telephonic work.

Ans. My experiments led me to that idea, — and of course I may be wrong, for I do not profess to be an expert in electrical matters. My experiments with tuned-reed receivers like those shown in Fig. 5 of my patent of March 7, 1876, seemed to indicate that I got as good effects with the coil on one leg of the electro-magnet, as shown in the drawings of that patent, as when two coils were used, one upon each leg. A single coil, therefore, seemed to be advantageous, as less expensive and more simple of construction. I also had the idea that the effects depended a great deal upon the magnetic condi-

tion of the iron core of the electro-magnet. These were the reasons that led me to adopt this form of electro-magnet in the apparatus shown in my patent of March 7, 1876. *

Cross-Int. 562. I wish you would explain a little more fully what idea you wish to convey by the expression, "the effects depended a great deal upon the magnetic condition of the iron core of the electro-magnet," in your last answer.

Ans. In the apparatus shown in my patent of March 7, 1876, and illustrated in Fig. 5 and Fig. 7, the steel-spring armature forms a part of the electro-magnet employed, being normally in magnetical contact with one of the poles, the free end of the armature projecting above the other pole. In Fig. 5 the armature is arranged as a free reed adapted to vibrate so as to produce a musical tone. In Fig. 7 the steel-spring armature is so arranged that it does not have a tendency to vibrate at a rate of its own, for it is attached loosely to the uncovered pole of the electro-magnet, while the other end is firmly fastened to the centre of a stretched membrane, so that the steel-spring armature is forced to copy the character of the motion of the membrane to which it is attached. When, therefore, a person utters a sound in the neighborhood of the membrane, the steel-spring armature attached to it is thrown into sonorous vibration and is forced by the membrane to copy the character or form of the aerial vibration. Both in the case of Fig. 5 and Fig. 7 two instruments of substantially similar construction are arranged upon the same circuit and a battery is employed to magnetize the cores of the electro-magnets. Under these circumstances the sonorous vibration of the free end of the steel armature in front of the pole of the electro-magnet creates electrical undulations upon the circuit analogous to sound vibrations, and the steel-spring armature of the receiving instrument is thrown into sonorous vibration by the varying attraction of its electro-magnet. For example, in the case of Fig. 7, if a person utters a sound in the neighborhood of the membrane *a*, the armature *c* is thrown into sonorous vibration in front of the pole of the electro-magnet *b*, thus creating electrical undulations upon the circuit *E b e f g*. These undulations are similar in form to the air-vibrations caused by the sound—that is, they are represented graphically by similar curves. The undulatory current passing

through the electro-magnet *f* influences its armature *h* to copy the motion of the armature *c*. A similar sound to that uttered into *A* is then heard to proceed from *L*. Now the electrical undulations considered are produced by the sonorous vibration of the steel-spring armature *c* in front of the pole of the electro-magnet *b*. The armature *c* is, in fact, an extension of the uncovered leg *d* of the electro-magnet, as it is normally in magnetical contact with the extremity of that leg. So that the magnetical condition of the whole arrangement seems to me to be similar to that of a straight rod bent into the shape *b d c*; *c* constituting one pole of the magnet so formed, and *b* the other pole. As the electrical effect is produced by the sonorous vibration of the one pole *c* in front of the other pole *b*, it seemed evident to my mind that the effect depended a great deal upon the magnetical condition of the bent magnet *b d c*. The more powerfully magnetical this could be made, the more powerful should the electrical undulations be, produced by the sonorous vibration of *c*. At the time I applied for my patent of March 7, 1876, I was inclined to think that a more powerful magnetic condition of the arrangement could be produced by passing a battery current through the coils of the electro-magnet than by having the whole arrangement permanently magnetized, and I considered that the arrangement of coil adopted in Fig. 7 was advantageous for this purpose.

Cross-Int. 563. From your last two answers I understand that no advantageous effect was obtained from placing the coil upon one pole or leg of the electro-magnet, instead of upon both, as shown in your patent No. 174,465, except that the construction of the electro-magnet was somewhat simpler. Do you claim any other advantage besides simplicity of construction?

Ans. My experiments led me to think that I got the best effects with that arrangement, and I have no doubt that such an arrangement of coil promoted the quick action of the magnet.

Cross-Int. 564. Do you remember whether Du Moncel, in the work to which you have referred, claims this advantage for the club-footed electro-magnet illustrated in your letter to Mr. Hubbard dated July 7, 1875?

Ans. I do not remember.

Cross-Int. 565. I notice that in your patent No. 186,787 (see

particularly Figs. 2 and 3), the coils are wound upon or near one of the poles of the electro-magnet, as in Fig. 5 and Fig. 7 of your patent No. 174,465. Do you also take the ground that this winding, as illustrated in Fig. 2 and Fig. 3 of your patent No. 186,787, promotes the quick action of the magnet?

Ans. I am inclined to think so; but at all events it promotes the efficiency of the apparatus in transmitting speech, as I found by numerous experiments.

Cross-Int. 566. Having reference to the electro-magnets shown in Figs. 2 and 3 of your patent No. 186,787, the degree of magnetization of the core will be proportional to the number of turns in the coil, will it not?

Ans. I presume so; but it is also dependent upon other circumstances, such as the proximity of the coils to the core, strength of battery, resistance of line, etc.

Cross-Int. 567. And if the wire is wound over the whole length of the bar F, in Fig. 2, there will be more turns than if it is piled up on one pole of the magnet, as shown in the figure, will there not?

Ans. I have no doubt so.

Cross-Int. 568. From your last two answers then it follows, does it not, that more current will be required to magnetize the bar F when the wire is piled up on one of the poles than when it is distributed the whole length of the bar? That is so, is it not?

Ans. I do not think so. As I understand the matter, when the wire is piled up near one pole of the bar, instead of being distributed uniformly over the whole surface of the bar, the effect is to increase the magnetical condition of that pole and weaken the other.

Cross-Int. 569. Upon what information is the statement contained in your last answer based?

Ans. Upon statements contained in the work of the Comte Du Moncel, to which I have before alluded, *Exposé des Applications de l'Électricité*.

Cross-Int. 570. From your letter to Mr. Hubbard, dated July 1, 1875, I gather that up to that time — July 1, 1875 — you had manufactured but one membrane instrument, and that up to that time

neither you nor anyone else had perceived the *timbre* of any sound made in the transmitter, and that up to that time the only receiver used with the one membrane telephone which you had constructed was a receiver known as the tuned-reed receiver. I am correct in this conclusion, am I not.

Ans. Not quite. I had perceived the *timbre* of a sound which had been transmitted electrically, on the 2d of June, 1875, on which occasion two tuned-reed receivers like those shown in Fig. 5 of my patent of March 7, 1876, were arranged as shown in that diagram, excepting that the battery was omitted. Mr. Watson had plucked the transmitting reed — say *c*, Fig. 5 — with his finger, while my ear was pressed firmly against the receiving reed *h*. I distinctly perceived from *h*, not only the pitch of the musical tone produced by *c*, but could also recognize the peculiar *timbre* characteristic of the pluck. I am inclined to think, from the letter to Mr. Hubbard, dated July 1, 1875, that only one membrane telephone had been constructed before July 1, 1875, and that the only receiver used with it before that date was a tuned-reed receiver, the reed of which was pressed firmly against the ear of the listener.

Cross-Int. 571. You spoke yesterday or day before of printed publications and drawings relating to a tubular electro-magnet, and you afterwards directed attention to a description of a tubular electro-magnet which you had read in a work of Du Moncel. What other printed descriptions of a tubular electro-magnet had you read besides that contained in the work of Du Moncel, if any?

Ans. I have seen other printed publications and drawings relating to tubular magnets, but I do not think that I saw them before the date of the construction of my iron-box receiver, in March, 1876, and I therefore presume they do not come within the scope of your question.

Cross-Int. 572. From your description of the tubular electro-magnet described in the work of Du Moncel, I did not get a very clear idea of the kind of armature that was used, as you understood it. What kind of an armature do you understand was used in the tubular magnet, the description of which you read in Du Moncel's work?

Ans. No armature at all was shown in the drawing, but if I

remember rightly, in the description of the drawing reference is made to an armature used with a three-pole electro-magnet as a suitable one to be used with the tubular magnet; and so far as I could make out from the drawing of the three-pole electro-magnet, the armature appeared to consist of a thick mass of metal placed near the poles of the magnet.

Cross-Int. 573. I gather from your last answer, that you read in Du Moncel's work the description of a tri-polar magnet, and also a description of a tubular magnet, and also a description of an armature for the tri-polar magnet, and that you concluded that the armature for the tri-polar magnet was to be used for the tubular electro-magnet. Is my conclusion correct?

Ans. Yes; excepting that it was not an assumption on my part that the armature of the tri-polar electro-magnet was to be used with the tubular electro-magnet, but was, so far as I remember, a direct statement contained in the work. I do not remember whether there was any other description of the armature referred to than the drawing. There may have been, but I do not recall it just now.

Cross-Int. 574. Taking the work of Du Moncel out of consideration, did you ever read any description of a tubular electro-magnet which did not have a circular-disk armature?

Ans. I presume you refer to a disk armature like that used in my iron-box receiver. I have never read any description of a tubular electro-magnet with such an armature, so far as I know, excepting descriptions of my own apparatus.

Cross-Int. 575. The one membrane instrument constructed by you prior to July 1, 1875, is, as I understand it, illustrated in your answer to Question 82. Please state which of the instruments illustrated in that answer was the one made prior to July 1, 1875.

Ans. The one first described in my answer to Interrogatory 82.

Cross-Int. 576. What has become of the instrument made prior to July 1, 1875, and first described in your answer to Question 82, and where did you last see it?

Ans. Portions of the apparatus are still in existence. I saw them quite recently in a trunk of old exhibits used in former telephone suits. I do not know what has become of the missing parts.

Cross-Int. 577. I gather from your last answer, that you have

recently seen the remnants or parts of this instrument. When did you last see the instrument as a whole, in complete working order?

Ans. I do not know. Not for a great many years.

Cross-Int. 578. I wish you would try and fix a date, as nearly as you can, when you last saw this instrument, as it is quite important that you should do so.

Ans. I have certainly not seen the instrument as a whole, in complete working order, since July, 1877, the date of my marriage. After that time I went abroad, and do not think I had any opportunity of seeing the apparatus again, until portions of it were produced in the *Dowd* suit.

Cross-Int. 579. Do you have any positive recollection of seeing this first instrument that was made and used prior to July 1, 1875, in complete working order in the year 1877?

Ans. No; I cannot be sure that it was in complete working order at that time. I cannot pretend to give the latest date when I saw it in working order.

Cross-Int. 580. Have you any positive recollection of seeing this first instrument which was used prior to July 1, 1875, in complete working order, during the year 1876?

Ans. I think I remember having seen it both in 1876 and 1877, but I cannot be sure that it was in complete working order at either of those dates.

Cross-Int. 581. When do you last remember to have seen it in complete working order during the year 1875?

Ans. I only know that it was used in June and July, 1875, and subsequently during that year, and then put on one side.

Cross-Int. 582. Please state a little more definitely what you mean by putting it "on one side." Was any attempt made to preserve it after its use in June and July, 1875?

Ans. Yes; the material parts of it were preserved, and are still in existence.

Cross-Int. 583. You refer to those parts of it which have been heretofore marked by the Examiner for identification in this cause, do you?

Ans. I am informed that the parts of it to which I have referred as having been in a trunk of old exhibits have been marked for

identification in this cause during the deposition of Mr. Thomas A. Watson.

Cross-Int. 584. In your letter to Mr. Hubbard referred to, of July 1, 1875, you spoke of your expectation of trying, on the following day, an experiment with another stretched membrane as a receiver. That is the second instrument referred to in your answer to Interrogatory 82, is it not?

Ans. I think so.

Cross-Int. 585. And what has become of that second instrument referred to in my last question, and when did you last see it in complete working order?

Ans. Parts of it are still in existence. I cannot be sure that I have seen it in complete working order since 1875. I think I remember seeing it both in 1876 and 1877, but whether it was in complete working order at those dates I do not know. Just before I went abroad (in 1877) I gave instructions to have this instrument, and everything else in my laboratory at Exeter Place, preserved. My impression is that all instruments, including this one, and all remnants of apparatus were packed up in boxes somewhere about August, 1877, and were placed at the disposal of the owners of my patents.

Cross-Int. 586. What time was it in 1875 when you last saw this instrument in complete working order?

Ans. I can only judge of the time by my letter of July 1 to Mr. Hubbard. It was after July 1, 1875.

Cross-Int. 587. Having reference to the two instruments described in your answer to Question 82, did any one except yourself and Mr. Watson experiment with them during the year 1875?

Ans. I do not now remember. It is very probable that the instruments may have been shown to Mr. Hubbard and Mr. Sanders, and perhaps to others, but I cannot now remember.

Cross-Int. 588. During the year 1875 and the year 1876 was any one except Mr. Watson employed in constructing your instruments?

Ans. I cannot tell. He was the person specially placed by Mr. Williams in charge of my apparatus, and so I presume my instruments were either constructed by him personally, or under his

direction. It may be possible that I had apparatus made in Canada, but I don't know.

Cross-Int. 589. Were the two membrane instruments referred to in your answer to Question 82 the only membrane instruments which were constructed by you or under your direction prior to March 7, 1876?

Ans. I am inclined to think they were the only membrane telephones constructed prior to that date, though, of course, I had made phonautographs and instruments of that description.

Cross-Int. 590. Can you give the date in 1875 of the last experiment that you tried with either of these membrane telephones?

Ans. No. My recollection of individual experiments made after the early part of July, 1875, is vague. From that time up to November, 1875, my mind was much worried by other matters, of a personal character, that left a much more distinct impression upon my memory than the experiments conducted within that period. I know that numerous experiments were made, but I cannot recall the details.

Cross-Int. 591. What is the last experiment, conducted during the year 1875, with these telephones that you distinctly recollect?

Ans. I remember trying two membrane telephones with Mr. Watson, connected together at Mr. Williams's place, and that sounds were transmitted. The voice of the speaker was clearly perceptible from the receiving telephone, the intonations being heard. Articulate sounds were also unmistakably transmitted, but it was difficult to make out what was said. Mr. Watson seemed to be able to hear a good deal better than I could, and my impression is that he stated he could almost make out what was said. I remember the fact of this experiment, but it was not the last. I remember that numerous other experiments were made subsequently, but I cannot recall the details of any particular experiment. I do remember, however, as the general result of all the experiments made, that I was encouraged to believe that I had solved the problem of the transmission of articulate speech by electricity, and that carefully constructed instruments, substantially similar to those I had made, would prove to be practically operative speaking telephones. While I cannot recall the result of particular experiments made during the period inquired about, I do have a very clear recollection of the general result of

them all. The statement of this result I have given above is confirmed by a contemporaneous document in the shape of a letter that I wrote to Mr. Hubbard, on August 14, 1875, summing up the results at which I had then arrived. I read this letter in my answer to Interrogatory 89.

Cross-Int. 592. Can you state positively that you made any experiments with the membrane telephones during the month of August, 1875?

Ans. I cannot. I only know that subsequently to the particular experiment alluded to in my last preceding answer, a great many experiments were made with membrane telephones, but I cannot recall the details of individual experiments.

Cross-Int. 593. Were all these experiments you refer to in your last answer made at Mr. Williams's shop?

Ans. I think so.

Cross-Int. 594. I understand you to have stated that Mr. Williams's shop was a noisy place. Why was not a more quiet place selected for these experiments?

Ans. I had made special arrangements to carry on my experiments at Mr. Williams's shop, and I was so satisfied in my own mind that I had solved the problem of the transmission of articulate speech, that I ventured to describe and claim my method and apparatus in a United States patent, without waiting for better results; in full confidence that the problem had been solved, and that my instruments would turn out to be operative speaking telephones. I was more concerned about taking out a caveat or patent than about further experiments. I believed I had experimented sufficiently to entitle me to a patent. This is shown by my letter of August 14, 1875, to Mr. Hubbard. After that date my efforts were chiefly directed to preparing a specification for a patent, and to getting people to help me to obtain foreign patents, as neither Mr. Hubbard nor Mr. Sanders cared to assist me in this respect. The specification referred to afterwards became my patent of March 7, 1876, No. 174,465. I was so impressed with the value of my invention, that I was not willing to take out a patent for it in the United States alone, but wished also to have it secured to me in other countries. Had it not been for my high appreciation of the invention, my patent of

March 7, 1876, might have been taken out months before, for the specification was commenced in September, 1875, and substantially completed by the middle of October, 1875.

There is another reason why I did not arrange in July, 1875, to secure a more quiet place than Mr. Williams's workshop in which to carry on my experiments. I have already alluded to the fact that my mind was much occupied and worried by other matters, not directly connected with my experiments, of a personal nature. I think it only right that I should state more clearly what I mean, as I am sure that a correct understanding of the condition of my mind at that time will explain my failure to remember details of experiments that I have no doubt I would otherwise have recalled, and my failure to preserve records of the experiments in the shape of notes and letters. It will also explain why it was that when my specification was completed, in October, 1875, I devoted myself for a time almost exclusively to my professional work, instead of carrying on my experiments. After the beginning of July, 1875, my mind was much worried and disturbed by difficulties of a personal nature between myself and Mr. Hubbard's family. I do not care to go into the details of these difficulties, but may say that they were not entirely removed until the 25th of November, 1875, when I became engaged to marry Mr. Hubbard's daughter.

Cross-Int. 595. In your answer to Cross-question 570 you say that you have perceived the *timbre* of a sound which had been transmitted electrically, on the 2d of June, 1875, on which occasion two tuned-reed receivers like those shown in Fig. 5 of your patent of March 7, 1876, were arranged as shown in that diagram, excepting that the battery was omitted. Is there anything in your patent of March 7, 1876, which indicates that one of the tuned-reed receivers, like those shown in Fig. 5, could be used as a receiver of the *timbre* of sound in connection with any transmitter?

Ans. Yes. I have shown in my patent of March 7, 1876, that if one of the tuned-reed receivers be so arranged that its steel-spring armature does not have a tendency to vibrate at a rate of its own, it can be used as a receiver of the *timbre* of sound, and I have, in Fig. 7, shown one way of arranging the steel reed in order to accomplish this result. Instead of being clamped firmly to the pole of its elec-

tro-magnet, as in Fig. 5, the steel spring is fastened loosely by one extremity to the uncovered leg of its electro-magnet, and its other extremity is attached to the centre of a stretched membrane. Of course a receiver, if arranged as in Fig. 5, with the armature in the shape of a free tuned-reed, is not adapted as a receiver of the *timbre* of sound. The tendency of a free tuned-reed to vibrate at a definite rate of its own interferes with the operation of the instrument as a receiver of *timbre*. In using such an instrument, therefore, as a receiver for the *timbre* of sounds, it is necessary to get rid of the free vibration of the reed. In my experiments of June 2, 1875, I did so by damping the reed by pressure against my ear. The method shown in Fig. 7 is an improvement upon this, because the reed armature is so arranged that it has no tendency to vibrate at a definite rate of its own; whereas, in the former plan, it had such a tendency, which had to be checked and prevented by pressure against the ear.

Cross-Int. 596. In your answer to Question 87 I understand you to say that in experimenting with the membrane telephones described in your answer to Question 82, you tried to get your mouth or ear, as the case might be, as close to the membrane as possible. Why, then, does Fig. 7 of your patent of March 7, 1876, show a receiver in which the ear cannot be placed very near the diaphragm, and a transmitter in which the mouth cannot be placed very near the diaphragm?

Ans. I believed that the addition to my membrane telephones of devices to aid the voice and ear would be advantageous. I thought that a cone A, Fig. 7, like that used in the operation of phonographs, would enable the voice of the speaker to set the membrane a into more powerful vibration, and that the employment of a hearing-tube or trumpet, L, like that used by deaf people, would increase the loudness of the sound heard by the listener.

Cross-Int. 597. In your letter to Mr. Hubbard, dated August 14, 1875, referred to in your answer to Question 89, you use the following language:

"Don't you think it would be well to take out a *caveat* for the use of the magneto-electric current? In its present undeveloped state, it might be unwise to let Gray know anything about it, unless indeed we could secure the *principle* of it in a patent."

This language is unintelligible to me in the absence of further explanation, although I get the impression from it that you and Mr. Hubbard had under consideration some communication with Gray. I should be glad if you would be kind enough to make the meaning of this passage clear.

Ans. No. We did not have under consideration the idea of any communication with Gray. It was known to me that Mr. Elisha Gray was a rival claimant for my invention of multiple telegraphy, in which Mr. Hubbard was specially interested, and I believed that an undulatory current would be of special value for the purposes of multiple telegraphy. During the year 1875, and up to the time this letter was written — August 14, 1875 — I had allowed myself to entertain ungenerous thoughts of Mr. Gray and believed him capable of spying upon me. Indeed this idea subsequently led me to remove my apparatus entirely from Mr. Williams's shop to private rooms at Exeter Place. My mind was so filled with suspicion, that I did not feel full confidence that I could safely have apparatus constructed until I had protected myself by obtaining a patent, or at least a *caveat*, for the undulatory current. I am inclined to think that this is the meaning of the passage referred to in my letter. I remember that Mr. Hubbard advised me not to apply for a *caveat*, as this was a confession of an incomplete invention, whereas he thought that I had developed my invention quite sufficiently to entitle me to a patent.

Cross-Int. 598. Mr. Hubbard was, I believe, a lawyer by profession, was he not?

Ans. I believe so.

Cross-Int. 599. In your answer to Question 90 I understand you to say that during August, 1875, your health became quite seriously impaired, and at last you went home to your parents in Canada to recruit. When was it that you went home to your parents in Canada as stated?

Ans. I cannot pretend to give the exact date from memory alone, but my father's diary shows that I arrived in Brantford on the 4th of September, 1875, and left Brantford on September 27, 1875. These diary entries I take from the printed record of my

father's deposition in the suit of *American Bell Telephone Company v. People's Telephone Company*.

Cross-Int. 600. In your letter to Mr. Hubbard, dated September 28, 1875, quoted in your answer to Question 93, you say :

"You must not think that I have been neglecting telegraphy during my visit to Canada. I brought a couple of instruments with me," etc.

These instruments to which you refer did not relate in any way to the transmission of articulate speech, did they?

Ans. The instruments referred to were multiple-telegraph instruments.

Cross-Int. 601. In your answer to Question 96, you read from a rough draft of a specification for your patent of March 7, 1876, as follows :

"It has long been known that when a permanent magnet is caused to approach the pole of an electro-magnet a current of electricity is induced in the coils of the latter, and that when it is made to recede a current of electricity of opposite polarity to the first appears upon the wire. When, therefore, a permanent magnet is caused to *vibrate* in front of the pole of an electro-magnet, an undulatory current of electricity is induced in the coils of the electro-magnet, the undulations of which correspond in number per second to the vibrations of the magnet—in polarity to the direction of motion of the permanent magnet—and in intensity to the amplitude of the vibration of the permanent magnet."

This statement was intended by you, was it, as a declaration of the state of the art as it existed prior to any invention made by you?

Ans. The first sentence of the paragraph quoted was intended as a declaration of the state of the art. The latter part, commencing

"When, therefore, a permanent magnet is caused to vibrate in front of the pole of an electro-magnet," etc., was a deduction of my own from the premises given in the first sentence.

Cross-Int. 602. Is there anything stated in the paragraph quoted by me in my last question which was not perfectly well known by electricians prior to the time that you had made any invention whatever? If there is any fact stated there that was not familiar knowledge prior to the time that you made your invention, I should be glad to have you point it out.

Ans. The facts alluded to in the first sentence, as the paragraph itself states, had "long been known," so that the state of knowledge was such that the consequences stated in the other portion of the paragraph might have been deduced from the premises given. I believe myself to have been the first person to have made the deduction. The fact, therefore, stated in the portion of the paragraph commencing

"When, therefore, a permanent magnet is caused to vibrate in front of the pole of an electro-magnet," etc.,

was not familiar knowledge prior to the time I made my invention.

Cross-Int. 603. Were not these facts constantly applied in the construction and operation of magneto-electric machines prior to the date of any invention made by you? And if there is any one or more of these facts that was not known to the operator or constructor of an ordinary magneto-electric machine, I should be very glad if you would inform the Court of it.

Ans. No magneto-electric machine or apparatus of any kind, prior to the date of my invention, made use of a current of electricity moulded into undulations analogous to sound vibrations produced by the sonorous vibration of a permanent magnet in front of the pole of an electro-magnet, or produced in any other way. These facts, therefore, were not applied in the construction and operation of magneto-electric machines or other apparatus prior to the date of any invention made by me.

In regard to the last part of the question, the facts stated in the first sentence of the paragraph you have quoted were known to the constructors of ordinary magneto-electric machines. There was nothing, therefore, in the state of the art to prevent anyone from making the deduction contained in the latter part of the paragraph; but the fact is, no one did make the deduction before I did so, so far as I know. The facts, therefore, stated in the latter part of the paragraph were not known to operators and constructors of ordinary magneto-electric machines before I divulged them to the public.

Cross-Int. 604. From your last answer I presume that you have entirely misunderstood my question. My question had no reference whatever to sound vibrations, or to sonorous vibrations, or to any invention made by you. I simply called your attention to a para-

graph said to have been written in lead pencil on a sheet of paper. My question was intended to apply to that, and to nothing over, beyond, or outside of that. With this explanation will you please answer the question?

Ans. The paragraph referred to was written by me, and was a rough draft of a paragraph that appears in my patent of March 7, 1876, No. 174,465. I presumed, therefore, that your question did have reference to my invention, and as my invention related exclusively to sound vibrations, or sonorous vibrations, I presumed that you intended me to give to the paragraph the meaning it was intended to have in my patent of March 7, 1876, No. 174,465, where all the vibrations referred to are sonorous vibrations, and all the electrical undulations alluded to are undulations analogous to aerial sound vibrations. My answer, however, is the same whether the vibrations referred to are taken to mean sonorous vibrations, or vibrations that are too slow to excite the sensation of sound. It does not make any difference in my reply, but I merely say that when I wrote the paragraph I intended it to refer to a sonorous vibration of the permanent magnet.

Cross-Int. 605. And you intend your last two preceding answers to apply to every fact stated in the paragraph to which you have referred, do you, without any exception whatever?

Ans. I intended them to apply to the second sentence of the paragraph alone, as the facts mentioned in the first sentence are stated in the paragraph itself to have "long been known." In order to make my meaning perfectly clear, I will say that the following part of the paragraph describes the facts that were well known before any invention by me.

"It has long been known that when a permanent magnet is caused to approach the pole of an electro-magnet a current of electricity is induced in the coils of the latter, and that when it is made to recede a current of electricity of opposite polarity to the first appears upon the wire."

What was not known before I divulged it to the world, but what might have been deduced from the premises just stated, but which was not deduced before I did it — so far as I know — is contained in the second sentence, which is as follows :

“When, therefore, a permanent magnet is caused to *vibrate* in front of the pole of an electro-magnet, an undulatory current of electricity is induced in the coils of the electro-magnet, the undulations of which correspond in number per second to the vibrations of the magnet — in polarity to the direction of motion of the permanent magnet — and in intensity to the amplitude of the vibration of the permanent magnet.”

No magneto-electric machine — so far as I know — prior to the date of my invention, made use of an electrical current induced in the coils of an electro-magnet by the vibration of a permanent magnet in front of the pole of the electro-magnet, in which the electrical undulations corresponded in number, per second, to the vibrations of the magnet — in polarity, to the direction of motion of the permanent magnet — and in intensity, to the amplitude of vibration of the permanent magnet, even though we include cases in which the vibration is too slow to produce the sensation of sound.

The fact that the vibration of a permanent magnet in front of the pole of an electro-magnet would induce a current that would correspond to the motion of the magnet in the particulars mentioned, could, I say, have been deduced from known premises, before I did it, but no one had made the deduction — so far as I know — before I myself made it; and this I say in regard to vibrations too slow to produce the sensation of sound, although in my patent of March 7, 1876, I intended to limit myself entirely to sonorous vibrations, or vibrations of such rapidity that they *would* produce the sensation of sound.

Cross-Int. 606. I will again call your attention to the club-footed electro-magnet of Du Moncel (referred to in your letter to Mr. Hubbard, of July 7, 1875), in which the armature is hinged to the uncovered leg of the magnet. Is it not a fact that when the armature of that magnet is caused to vibrate in front of the electro-magnet, currents of electricity are induced in the coils of the electro-magnet, which correspond in number, per second, to the vibrations of the armature; in polarity, to the direction of motion of the armature; and in intensity, to the amplitude of vibration of the armature? In asking this question, I have no reference to any inventions made by you at any time.

Ans. Yes; if means are provided to cause the armature to vibrate freely without touching the pole of the electro-magnet

underneath it; but I do not think that any one knew this before my own invention, or that any one did actually cause the vibration of such an armature in the manner supposed; and certainly no one knew or imagined, before I did, that the sonorous vibration of such an armature in front of the pole of its electro-magnet would induce in the coils of the electro-magnet a current of electricity moulded into undulations like sound vibrations. The question, of course, assumes that the coil of the electro-magnet forms a portion of a closed circuit, and that the armature vibrates in a magnetic field.

Cross-Int. 607. In the passage from your specification to which your attention has been called, you say :

“It has long been known that when a permanent magnet is caused to approach the pole of an electro-magnet a current of electricity is induced in the coils of the latter, and that when it is made to recede, a current of electricity of opposite polarity to the first appears upon the wire.”

It had also long been known, had it not, that when the armature of an electro-magnet placed in a battery circuit is caused to approach the pole of the electro-magnet, a current of electricity is induced in the coils of the latter, and that when the armature is made to recede, a current of electricity of opposite polarity to the first is induced upon the wire?

Ans. I do not know. I presume it could have been deduced from the first fact stated, even if it had not been actually known. I presume it could have been deduced that the magneto-electric currents induced by the motion of the armature would have been superposed upon the current due to the battery, so that a resultant effect would have been produced upon the circuit. It would not, therefore, necessarily be true that a current of opposite polarity would appear upon the wire. The current might be of the same kind and of the same polarity throughout, but varying in strength.

Cross-Int. 608. You have stated to me before the opening of the session this morning, that you desired to correct some portion of your testimony yesterday. I am willing that you should now have an opportunity of so doing.

Ans. In Cross-interrogatory 597, you quoted the following passage from my letter to Mr. Hubbard of August 14, 1875 :

"Don't you think it would be well to take out a *caveat* for the use of the magneto-electric current? In its present undeveloped state, it might be unwise to let Gray know anything about it, unless indeed we could secure the *principle* of it in a patent";

and you requested me to make the meaning of the passage clear.

In my reply I stated that "We did not have under consideration the idea of any communication with Gray." Since giving my testimony yesterday, my attention has been directed to my letter of May 4, 1875, addressed to Mr. Hubbard, a portion of which was read in answer to direct Interrogatory 59. Interrogatory 59 requested me to read from the letter that part which begins at the top of the third page, and from thence to the end. I did not, therefore, read pages one and two of the letter. I will do so now, as the matter seems to have some bearing on the meaning of the passage you have quoted, in Cross-interrogatory 597, from my letter of August 14, 1875, to Mr. Hubbard. My letter to Mr. Hubbard of May 4, 1875, the original of which I hold in my hand, commences as follows:

SALEM, MASS., May 4th, 1875.

DEAR MR. HUBBARD:

Mr. Sanders and I had an interview with Mr. Hayes to-day. I was careful what I told him. He seemed, I think, impressed by what I *did* say, and urged very strongly a union of interest between Mr. Gray and myself. I spoke very undecidely on the subject — gave the impression that I was rather belliciously inclined than otherwise — but expressed my willingness to be guided by my partners.

Of course, could not come to any decision as to what was best until I had had the opportunity of making Mr. Gray's acquaintance, and of knowing definitely how much had been accomplished by him.

Expressed my willingness to let Mr. Hayes see some of my instruments at work, and for that purpose invited him to visit me in Salem. He is to come on Friday afternoon. Should you be in town at that time, I should like to have you come too. Mr. Stevens, of Salem, has kindly permitted me to make connection with his city circuit, so that I can now bring the full power of his large battery to bear upon my instruments in my own study. I don't propose to have Mr. Hayes enter my *sanctum sanctorum*.

I shall carry a wire down stairs into one of the parlors, and merely show some of the receiving instruments with vibratory circuit-breakers and Morse sounders attached.

The rest of the letter is given in my answer to Interrogatory 59. Mr. Hayes was Mr. Elisha Gray's solicitor of patents at that time, I

believe. I had forgotten the fact that Mr. Hayes had urged upon myself and partners a union of interest between Mr. Gray and myself, until my memory was refreshed yesterday, after giving my answer to Cross-interrogatory 597, by the perusal of the portion of my letter of May 4, 1875, which I have quoted above. I am now inclined to think that, at the time that my letter of August 14, 1875, was written, Mr. Hubbard may have had under consideration some proposition to unite interests with Gray, and that I desired Mr. Hubbard should say nothing to Mr. Gray or his solicitors about my magneto-electric current until I had applied for a *caveat* or patent, so that there should be no doubt who was the inventor. I have done my best to explain the meaning of the paragraph quoted, in your Cross-interrogatory 597, from my letter of August 14, 1875, to Mr. Hubbard; but it is, of course, difficult, after the lapse of so many years, to state definitely exactly what I did mean.

Cross-Int. 609. In your patent No. 174,465, you say :

"There are many ways of producing undulatory currents of electricity, dependent for effect upon the vibrations or motions of bodies capable of inductive action. A few of the methods that may be employed I shall here specify. When a wire, through which a continuous current of electricity is passing, is caused to vibrate in the neighborhood of another wire, an undulatory current of electricity is induced in the latter. When a cylinder, upon which are arranged bar-magnets, is made to rotate in front of the pole of an electro-magnet, an undulatory current of electricity is induced in the coils of the electro-magnet."

I do not find this paragraph in the rough draft of your specification referred to in your answer to Question 95. Do you have any recollection when you first prepared that paragraph?

Ans. In my answer to direct Interrogatory 95, I identified seven sheets constituting fragmentary remains of rough drafts of the specification for my patent of March 7, 1876; and in answer to direct Interrogatory 96, I read from these sheets such passages as were pointed out to me by counsel. Rough drafts of the paragraph you have quoted appear on some of the sheets identified in answer to Interrogatory 95, but were not read in answer to Interrogatory 96. The paragraph was substantially completed in October, 1875.

Cross-Int. 610. Was the paragraph quoted in my last question a

declaration of the state of the art as it existed prior to any invention made by you?

Ans. No. In my patent I described certain instrumentalities shown in Fig. 5 and Fig. 7, for producing undulatory currents of electricity suitable for purposes of multiple telegraphy and speech-transmission; and in the paragraph you have quoted, I tried to indicate some equivalent means for producing electrical undulations like sound vibrations.

Cross-Int. 611. What fact is stated in the paragraph quoted, which was not known to those skilled in the art prior to the date of any invention made by you? Of course, my question has reference simply to the paragraph quoted, and not to other parts of the specification of either of your patents.

Ans. That electrical undulations analogous to sound vibrations could be produced by the means stated.

Cross-Int. 612. One of the facts stated in that paragraph is thus worded:

“When a cylinder, upon which are arranged bar-magnets, is made to rotate in front of the pole of an electro-magnet, an undulatory current of electricity is induced in the coils of the electro-magnet.”

You mean by your last answer, do you, that electrical undulations analogous to sound vibrations could be produced by that means?

Ans. In order that I may make my meaning perfectly clear, I may say, that on the 15th of December, 1874, I made a discovery which is described in a letter that I wrote to Dr. Clarence J. Blake on that same day, and which I read in my answer to direct Interrogatory 43. In that letter, I say:

“A number of permanent magnets were arranged upon a cylinder (see illustration) which was revolved in front of electro-magnets. On filling my ears with water and applying the wires (protected, of course) as in the diagram, a soft musical note was heard.”

This was the experiment to which I refer in my application of March 10, 1875, as follows:

“I have created a regular oscillation of the induced current by means of permanent magnets in the place of batteries. Bar-magnets G, with poles arranged as shown, were placed on the surface of a revolving cylinder with several electro-magnets E placed opposite to them, as shown in Figure 4, the space between any two adjoining

magnets being equal in breadth to the pole of the electro-magnet opposed to it.

"Under this arrangement, when the cylinder was revolved, direct and reversed induced currents came at equal intervals apart, making electrodes of the earth and line wires *a*, *b*. With this instrument, the induced currents passed directly through the ears, created in the ear itself the perception of a musical note, without the intervention of any receiving instrument whatever."

I may remark in passing that there is a slight error in the reference marks. Fig. 4 should be Fig. 3, and G should be M. Now, when I took out my patent of March 7, 1876, I had arrived at the conception of what I termed an undulatory current of electricity; a current in which the electrical undulations were analogous to sound vibrations; a current characterized by changes of intensity exactly analogous to the changes in the density of the air when transmitting sound vibrations; and in that patent I showed means, illustrated in Figs. 5 and 7, whereby electrical undulations like sound vibrations could be produced. For example, in regard to Fig. 5, I said:

"In illustration of the method of creating electrical undulations, I shall show and describe one form of apparatus for producing the effect. I prefer to employ for this purpose an electro-magnet A, Fig. 5, having a coil upon only one of its legs *b*. A steel-spring armature *c* is firmly clamped by one extremity to the uncovered leg *d* of the magnet, and its free end is allowed to project above the pole of the covered leg. The armature *c* can be set in vibration in a variety of ways, one of which is by wind, and, in vibrating, it produces a musical note of a certain definite pitch."

Having described definite means for producing an entirely new thing, to wit, an electrical current moulded into undulations exactly analogous to sound vibrations, I believed myself entitled to claim all equivalent means for producing the same result, whether I specified such means or not. I thought it well, however, to speculate upon the subject, and to describe in my application such alternative means as occurred to me. For example, it seemed to me that it might be possible to arrange bar-magnets upon a cylinder in such a manner that when the cylinder was rotated in front of the pole of an electro-magnet, a current should be induced exactly like that produced by the vibration of the armature *c*, Fig. 5; and I therefore, in my patent, suggested this means as an alternative for that shown in Fig. 5.

Cross-Int. 613. Did you ever make any apparatus in which this means which you suggested as an alternative for the apparatus described in Fig. 5 was used? I refer to the statement contained in the last line or two of your last answer.

Ans. No.

Cross-Int. 614. As you have testified that you drew the claims of your patent No. 174,465, I will ask you whether there is any claim in that patent which refers to this means as an alternative for that shown in Fig. 5.

Ans. I presumed that the claims of the patent would cover all equivalent means to those described, and I believed, therefore, that if it should turn out that bar-magnets could be used on a rotating cylinder to produce in the coils of an electro-magnet electrical undulations analogous to sound vibrations, like those produced by the apparatus shown in Fig. 5, the claims of the patent would cover this as an equivalent of the means shown in Fig. 5.

Cross-Int. 615. When, if ever, did you become acquainted with the inventions disclosed in the British patent granted to C. F. Varley, No. 1044, of 1870?

Ans. I cannot tell whether I ever became acquainted with them, without consulting a copy of the patent to which you refer.

Cross-Int. 616. The paragraph to which I referred also contains the following assertion:

“When a wire, through which a continuous current of electricity is passing, is caused to vibrate in the neighborhood of another wire, an undulatory current of electricity is induced in the latter.”

Did you ever construct such an apparatus, or did you ever induce an undulatory current of electricity by such means?

Ans. Yes. I have done so.

Cross-Int. 617. Was this apparatus constructed before the date of your patent of March 7, 1876?

Ans. No. Not until after.

Cross-Int. 618. Please describe briefly the apparatus to which you have referred in your last two answers.

Ans. A flat spiral of insulated wire was carried by a diaphragm in place of the armature *c*, Fig. 7, and vibrated by the action of the voice in front of the pole of an electro-magnet which was in a voltaic

circuit, as shown in Fig. 7. The flat spiral was connected with a local circuit of its own containing a battery. I think I tried the effect of removing the iron core from the electro-magnet. I have a recollection also, of having made experiments in vibrating one electro-magnet in front of the pole of another. The movable electro-magnet was carried by a diaphragm which was set in vibration by the voice of the speaker. These electro-magnets were tried with and without iron cores, and in separate circuits with a battery in each circuit, and also in a single circuit containing a battery.

Cross-Int. 619. Is there any claim of your patent which refers to the method of inducing an undulatory current of electricity, stated in the following paragraph of your patent :

“When a wire, through which a continuous current of electricity is passing, is caused to vibrate in the neighborhood of another wire, an undulatory current of electricity is induced in the latter.”

Ans. I believed that any of the claims in which this could be shown to be a mere alternative for the means actually described would cover it; but the method is itself specifically claimed in the 3d claim.

Cross-Int. 620. The following statement is also found in your patent of March 7, 1876 :

“Undulations are caused in a continuous voltaic current by the vibration or motion of bodies capable of inductive action, or by the vibration of the conducting-wire itself in the neighborhood of such bodies.”

Does any claim of the patent refer specifically to this method of producing electrical undulations?

Ans. Yes. The 3d claim refers specifically to it.

Cross-Int. 621. No apparatus is illustrated, I believe, in the patent, showing the method of producing electrical undulations referred to in my last question?

Ans. Yes. The apparatus shown in Fig. 5 and Fig. 7.

Cross-Int. 622. How would electrical undulations be produced by the apparatus shown in Fig. 5, by the vibration of the conducting wire itself in the neighborhood of a body capable of inductive action?

Ans. The claim is not limited to the vibration of the conducting wire itself in the neighborhood of a body capable of inductive action. In the case of Fig. 5, electrical undulations are produced in a con-

tinuous voltaic current traversing the circuit $g b e f g$ by the vibration of the steel-spring armature c , which is a body capable of inductive action. The 3d claim specifically covers this method.

Cross-Int. 623. My last question did not have any particular reference to the 3d claim. What I desired to ask was whether there is any apparatus described in the patent through the agency of which undulations may be caused in a continuous voltaic current by the vibration of a conducting wire in the neighborhood of a body capable of inductive action.

Ans. Yes. Instrumentalities are shown in the patent, in Fig. 5 and in Fig. 7, whereby sonorous vibrations can be imparted to any body it is desired to set into vibration. For example, in Fig. 5 the vibratory part of the apparatus consists of a reed which, it is stated in the patent, can be set in vibration in a variety of ways, and specifically by wind, as in the case of any ordinary reed musical instrument. In the case of Fig. 5, the body capable of inductive action is vibrated in the neighborhood of the conducting wire. If, then, we desire to adopt the alternative method of vibrating the conducting wire in the neighborhood of the body capable of inductive action, we should attach the conducting wire to the reed c , Fig. 5, and substitute a body capable of inductive action for the electro-magnet b . The mechanical means of throwing a body into sonorous vibration so as to produce a musical note of definite pitch, which is specifically described in the patent, is a reed blown by wind. If the body to be thrown into vibration be some material capable of inductive action, like steel, it is sufficient to make the reed of that material, or to attach material of the kind required to a reed of ordinary construction. Or if the body to be thrown into sonorous vibration to produce a musical tone be the conducting wire itself, it is sufficient to attach the conducting wire to a reed of ordinary construction.

The mechanical means, specifically described in the patent, of causing a body to be moved by the sonorous vibration of the air while transmitting a sound, so that the body shall copy the form of the aerial sound vibration and move itself as the air moves during the transmission of the sound, is a stretched membrane, as shown at a in Fig. 7, which can be set in vibration by the human voice or by sounds produced in any way in its neighborhood.

In the operation of the apparatus as arranged in Fig. 7 the membrane *a* is used to cause the vibration of a body attached to it, capable of inductive action, in the neighborhood of the conducting wire. If, then, we desire to adopt the alternative method of vibrating the conducting wire in the neighborhood of a body capable of inductive action, we should attach the conducting wire to the membrane *a*, Fig. 7, and have at *b* a body capable of inductive action. In my answer to Cross-interrogatory 618 I described experiments that were actually made in pursuance of this plan. Speech was transmitted in this way.

Cross-Int. 624. In your answer to Cross-interrogatory 614 you said: "I presumed that the claims of the patent would cover all equivalent means to those described." Did you mean by this answer that any one of the claims of the patent would cover all equivalent means to those described?

Ans. Yes; to those described as applicable to that claim.

Cross-Int. 625. Please make your answer a little more specific and state those which are applicable.

Ans. I think that means specifically described in the patent are applicable to all the claims.

Cross-Int. 626. In order that your answer may be precisely understood, will you please state what means specifically described in the patent you refer to in your last answer?

Ans. Means illustrated by Fig. 5 or Fig. 7.

Cross-Int. 627. Having reference to your answer to Cross-question 623, will you please state the breadth and thickness which the reed *c*, shown in Fig. 5, should have, as I do not find its breadth shown in any illustration forming part of the patent?

Ans. The exact breadth or thickness is immaterial to the electrical operation of the instrument, so long as the reed can be thrown into vibration by wind after the manner of a reed of an ordinary wind musical instrument. The instruments shown at each station in Fig. 6 have each a different pitch or rate of vibration, and hence the reeds might each have a different breadth or thickness. The breadth and thickness depend upon the pitch of the musical tone it is desired to produce, and might be the usual breadth and thickness of the reeds of corresponding pitch of any ordinary wind musical instrument.

Cross-Int. 628. What form may the reed *c*, Fig. 5, have?

Ans. The form of ordinary reeds employed in wind musical instruments.

Cross-Int. 629. Do your last two answers relating to the armature *c* shown in Fig. 5, apply also to the armature *c* shown in Fig. 7?

Ans. They apply in this respect: that the breadth or thickness of the steel-spring armature *c* is immaterial to the electrical operation of the apparatus shown in Fig. 7; so that any of the steel reeds illustrated in Figs. 5 or 6 would do — if, instead of being arranged as a free tuned-reed to be blown by wind, it should be fastened loosely by one extremity to the uncovered leg of its electro-magnet, and have its other extremity attached to the centre of a stretched membrane, as shown in Fig. 7. The reed *c* of the instrument shown in Fig. 5 is adapted to vibrate well at one particular rate alone, so as to produce a musical note of a certain definite pitch; and the instruments shown at each station in Fig. 6 have each a different pitch, so that the reeds have to differ from one another in breadth, thickness, etc., to adapt them to vibrate at the definite rate desired, as in the case of the reeds of an ordinary wind musical instrument. In the case shown in Fig. 7, however, the steel-spring armature *c* is specially arranged so that: (1) By its loose connection with the electro-magnet it shall *not* have a tendency to vibrate at one particular rate alone; and (2) By its firm connection with the stretched membrane *a* it may be forced to vibrate with substantially equal freedom at all rates, and copy, not only the frequency of an aerial sound vibration occurring in the neighborhood of the membrane *a*, but even the very form of the sound vibration itself. Hence, the conditions required in the steel-spring armature *c*, Fig. 7, are very different from those of the reed armature *c*, Fig. 5; and it should be so adapted as to be easily vibrated by a stretched membrane under the influence of the voice.

Cross-Int. 630. As nothing is said in your patent No. 174,465 about the breadth or form of the armatures *c* and *h* of the instruments shown in Fig. 7, and as the claims of that patent were prepared by you, and you therefore know what they were intended to cover, I will ask you to state what length, breadth and thickness the armatures *c* and *h* may have, within the intended scope of the claims;

and also what material said armatures may be composed of, within the intended scope of the claims.

Ans. I did not intend to limit myself to any particular length, breadth, thickness or material. You have assumed that nothing is said in my patent No. 174,465 about the breadth and form of the armatures *c* and *h*, Fig. 7; but I have stated in the specification, that these armatures may have the form, etc., of a steel reed like that shown at *c* in Fig. 5. only, instead of arranging it as a free reed to be blown by wind, it is to be fastened loosely by one extremity to the uncovered leg *d* of the electro-magnet *b*, and its other extremity is to be attached to the centre of a stretched membrane *a*, as in Fig. 7.

Cross-Int. 631. Please quote the passage from the specification referred to by you in your last answer.

Ans. "One of the ways in which the armature *c*, Fig. 5, may be set in vibration has been stated above to be by wind. Another mode is shown in Fig. 7, whereby motion can be imparted to the armature by the human voice or by means of a musical instrument.

The armature *c*, Fig. 7, is fastened loosely by one extremity to the uncovered leg *d* of the electro-magnet *b*, and its other extremity is attached to the centre of a stretched membrane *a*."

Cross-Int. 632. I do not understand that the passage which you have just quoted refers in any way to the breadth or form of the receiving armature *h*. I shall be obliged to ask you for a little further explanation.

Ans. The drawing, Fig. 7, shows at the receiving end of the circuit an electro-magnet *f*, armature *h*, and membrane *i*, exactly similar to the electro-magnet *b*, armature *c*, and membrane *a*, at the transmitting end.

Cross-Int. 633. Having reference to your answer to Question 97: Have you any means of knowing whether the rough draft of your letter to Barclay, mentioned in your answer, was written before the rough draft on the other side of the sheet was written?

Ans. I have means of knowing that the rough draft of the letter to Mr. Barclay was written after the rough draft on the other side of the sheet, which formed a portion of the specification for my patent of March 7, 1876. I remember that at the time I was at work upon the preparation of the specification referred to, in the early part of

October, 1875, it was my custom, after studying the phraseology and making such changes and corrections as occurred to me, to make a clean copy of the revised passages upon another sheet of paper, and throw aside the old copy as waste paper; and that I utilized the blank portions of these sheets of paper thus thrown on one side, in making rough drafts of letters, calculations involving figures, etc., so that in any case of one of these sheets of paper having two rough drafts — one a portion of the specification, and the other a rough draft of a letter or calculation — I should have no hesitation in asserting positively from my memory alone, that the rough draft of the specification was written first.

I know that the rough draft of the letter to Mr. Barclay, referred to in your question, was written after the rough draft on the other side of the sheet, for another reason. I know that the specification of my patent of March 7, 1876, was substantially completed before the middle of October, 1875; whereas the rough draft of my letter to Mr. Barclay was written in response to a note received from him dated the 22d of October, 1875; and the rough draft itself was written between the 22d of October and the 4th of November, 1875, as I have stated in my answer to Interrogatory 97.

. Additional confirmation of my memory upon this matter is to be found in the following fact: The rough draft of my letter to Mr. Barclay on sheet 4 is written in ink, and the last few words of it are written over a portion of the rough draft of my specification, which portion is written in pencil.

Cross-Int. 634. I understand you to say, in answer to Question 99, that you were chiefly occupied in preparing your specification for the patent of March 7, 1876, in the early part of October, 1875, immediately upon your return from Canada. Did you have any professional assistance or advice in preparing that specification?

Ans. No. I had nothing to help me excepting the experience I had gained in Washington in February and March, 1875, during the preparation of my applications for letters patent, filed February 25, 1875, March 6, 1875, and March 10, 1875.

Cross-Int. 635. I notice that in the letter from your attorneys dated January 18, 1876, which you quoted in answer to Question 101, no mention is made of a model. Had any correspondence taken

place between you and your attorneys before January 18, 1876, in relation to a model to be used in the application referred to in the letter?

Ans. No. I was never asked for a model.

Cross-Int. 636. You mean by your last answer, do you, that prior to January 18, 1876, you had never been asked to furnish a model as a part of your application filed February 14, 1876, by any one, either by letter or by oral communication?

Ans. I have no recollection of having been asked by any one, but, whether this is so or not, I know certainly that no model was required by the Commissioner of Patents.

Cross-Int. 637. Was any model ever constructed by you, or under your instructions, for the application filed February 14, 1876?

Ans. Models were prepared to illustrate certain portions of the inventions described in the application filed February 14, 1876. These models were given to the Honorable George Brown, and they were taken by him to England. I should have been very glad to have filed models in the case of the American application, had this been required by the Commissioner.

Cross-Int. 638. What parts of the application filed February 14, 1876, did the models referred to in your last answer illustrate?

Ans. The multiple-telegraph parts, in which Mr. Brown was specially interested.

Cross-Int. 639. Then, if I understand you correctly, these models did not illustrate the apparatus shown in Fig. 7 of your patent No. 174,465, but they did illustrate the apparatus shown in Figs. 5 and 6 of your said patent?

Ans. The model I have specially in mind consisted of a transmitting instrument like that shown in Fig. 5 of my patent of March 7, 1876, with the steel reed *c* arranged like the free reed of a wind musical instrument, so that it could be blown by wind. There was also a model of a receiving instrument, like I, Fig. 5, with a vibratory circuit-breaker attached, like that shown in my patent of June 6, 1876, No. 178,399.

Cross-Int. 640. To your knowledge, was any model made in Washington after January 18, 1876, of the apparatus described in Fig. 7 of your patent No. 174,465?

Ans. No model was required by the Commissioner of Patents, and I do not think any was made.

Cross-Int. 641. Prior to the issue of your patent of March 7, 1876, was any test made in the city of Washington of any of the apparatus described or shown in your patent No. 174,465?

Ans. I do not think so.

Cross-Int. 642. From your last answer and your testimony heretofore given in this cause, I conclude that no instrument or model similar in all respects to the apparatus illustrated in Fig. 7 of your patent of March 7, 1876, was made or tested anywhere prior to the grant of the patent. That conclusion is correct, is it?

Ans. Instruments or models substantially similar to the apparatus illustrated in Fig. 7 of my patent of March 7, 1876, were made and tested in Boston, prior to the issue of my patent, in June and July, 1875. The instruments referred to differed from the instruments shown in Fig. 7 simply in not being provided with a cone A, or hearing-trumpet L.

Cross-Int. 643. But no such tests as those mentioned in your last answer were ever made in the city of Washington prior to the grant of your patent of March 7, 1876. That is so, is it not?

Ans. Yes. That is so.

Cross-Int. 644. Was any test of any kind made with any instrument for the purpose of ascertaining its capacity to transmit articulate speech prior to the seventh day of March, 1876, in the city of Washington?

Ans. Not in the city of Washington, so far as I know.

Cross-Int. 645. I understand you to say, in answer to Question 102, that the Honorable George Brown, of Toronto, and his brother, Mr. Gordon Brown, desired that the specification upon which you were at work in September, 1875, should not be filed in the United States Patent Office until they had time to take out patents simultaneously in Europe. In what countries in Europe did they propose to take out patents simultaneously to your American patents?

Ans. In Great Britain and perhaps other countries. I do not now remember exactly what our understanding was, but I think that the Honorable George Brown was to be the judge as to

what other countries besides Great Britain the patents were to be taken in.

Cross-Int. 646. I gather from your last answer and the testimony in this cause, that the Messrs. Brown had the idea that the filing of an application for an American patent would interfere in some way with the taking out of a patent in England. Was that the case?

Ans. I presume that they thought that if the patent was taken out in the United States before it was in England, it would interfere with the validity of the English patent. At least, that is my impression.

Cross-Int. 647. Was any attempt ever made at any time in the city of Washington to make a model similar to that illustrated in Fig. 7 of your patent No. 174,465, prior to March 7, 1876; or was any attempt ever made to experiment with such an apparatus in the city of Washington prior to the grant of the patent of March 7, 1876? I mean by the word "attempt" any steps whatever towards the construction of a model or towards experimenting with the apparatus.

Ans. No. Not in the city of Washington prior to March 7, 1876 — that is, so far as I know. Of course, such attempts were made in Boston prior to that date, as I have already testified.

Cross-Int. 648. And no attempts were made in Boston or anywhere else, to your knowledge, prior to March 7, 1876, except those about which you have already testified. That is so, is it not?

Ans. Yes. That is so.

Cross-Int. 649. You say, in answer to Question 102, that Mr. Hubbard privately instructed your solicitors to file the specification in the American Patent Office on the 14th of February, 1876, and it was so filed, without your knowledge or consent. Did Mr. Hubbard ever state to you his reasons for ordering the application to be filed in this way?

Ans. You have misunderstood me if you thought I said that Mr. Hubbard instructed my solicitors to file the specification on the 14th of February, 1876. I do not know the date on which he instructed my solicitors to file the specification; I simply know that he was tired of waiting for word from the Honorable George Brown, and

determined to wait no longer, and so he told my solicitors to go ahead and file the specification. I do not know the date he told them this, but they filed the specification on the 14th of February, 1876, without my knowledge.

Cross-Int. 650. Was your application for a patent for the spark-arrester, mentioned in your answer to Question 103, ever filed in the United States Patent Office?

Ans. An application was prepared and was forwarded to Washington for the purpose of being filed, but by advice of counsel it was not filed.

Cross-Int. 651. Do you mean by your last answer that an examination was made by counsel as to the novelty and patentability of the device, and upon such examination advice was given not to prosecute the application on account of the want of novelty of its subject-matter?

Ans. An examination was made by counsel and they advised against applying for a patent.

Cross-Int. 652. I notice that no mention is anywhere made in the specification quoted in your answer to Question 103 of the use of the spark-arrester as a variable-resistance transmitter. When, if ever, did you first suggest that such an apparatus might be used as a variable-resistance transmitter, and to whom did you make the suggestion?

Ans. The spark-arrester alluded to in the specification quoted in answer to Interrogatory 103, suggested to my mind the variable-resistance clause in my patent of March 7, 1876, commencing: "Electrical undulations may also be caused by alternately increasing and diminishing the resistance of the circuit," etc., down to "alternately increasing and diminishing the power of the battery," and the 4th claim of the patent, as I have explained in answer to Interrogatory 103. Very shortly after the grant of the patent, I think on March 9, 1876, Mr. Watson made a variable-resistance transmitter for me on the principle of the spark-arrester. Indeed I am inclined to believe that one of my spark-arresters was actually used in the construction of that transmitter.

Cross-Int. 653. You also say, in answer to Question 103, that almost at the last moment before sending your specification to

Washington to be engrossed, you discovered that you had neglected to include in it the variable-resistance mode of producing electrical undulations upon which you had been at work in the spring of 1875, and which you described to Mr. Hubbard in your letter to him of May 4th of that year. When did you first make a drawing or model showing the variable-resistance mode of producing electrical undulations thus referred to in your answer to Question 103?

Ans. I described this variable-resistance mode of producing electrical undulations, in my letter to Mr. Hubbard of May 4, 1875, which I read in my answer to Interrogatory 59. I attempted to reduce it to practice, by an experiment upon one of Mr. Fenollosa's pianos, very shortly after the writing of that letter of May 4, 1875. The experiment, however, was not satisfactory, on account of the construction of the piano; the strings being metallically connected together, if I remember rightly, and the experiment was not again repeated until after the issuance of my patent of March 7, 1876. I think the model and experiment to which I refer were made in 1879, as described in my answer to Interrogatory 62.

Cross-Int. 654. I believe it is a fact, is it not, that Honorable George Brown did not take out a patent for you in any foreign country?

Ans. That is a fact.

Cross-Int. 655. I understand you to say, in answer to Question 105 and prior questions, that your specification executed January 20, 1876, was filed February 14, 1876, without your knowledge or consent, but that when that fact came to your knowledge, the prosecution of the application was carried on with your consent and approval. You were, were you not, during the month of February, 1876, within the reach of telegraph communication, or communication by letter?

Ans. Yes.

Cross-Int. 656. Having reference to your answer to Question 113, please state when your associates, Mr. Sanders and Mr. Hubbard, first became aware of the fact that you had succeeded in transmitting articulate speech with a liquid transmitter.

Ans. I do not know. Probably shortly after the experiment had been made.

Cross-Int. 657. You state in your answer to Question 113 that Messrs. Sanders and Hubbard had the idea that the development of multiple telegraphy would prove of more immediate pecuniary value than the other features of your invention. Did they continue to have that idea, after they became acquainted with the fact that intelligible, articulate speech had been transmitted?

Ans. Yes; I think they continued to have that idea. At all events, they were anxious that I should devote a large portion of my time to the development of the autograph telegraph, for which I had obtained a patent on April 6, 1875, and in which they were pecuniarily interested.

Cross-Int. 658. They were interested in all your inventions, were they not, under the agreement made with them?

Ans. There was a difference of opinion among us upon that point. Either Mr. Hubbard or Mr. Sanders, I do not remember now which, had the idea that the speaking telephone did not come within the scope of our agreement, but I thought it did. At a later date, when it was seen that the telephone was going to be of value, it was agreed to consider it as coming under our agreement.

Cross-Int. 659. Having reference to your last answer: When was it first seen that the telephone was going to be of value? Please fix that date as nearly as you can.

Ans. I always believed it to be of value; but I do not think that business men realized the pecuniary value of the speaking telephone, till long after its first introduction into commercial use, which was, I think, in May, 1877.

Cross-Int. 660. What idea did business men have of the telephone, prior to its introduction into commercial use, in May, 1877?

Ans. I cannot pretend to say. I know they considered it a very wonderful thing as a scientific achievement, but I do not think they had any idea that the invention would prove to be so useful to the public as time has shown it to be; and they certainly undervalued its pecuniary importance.

Cross-Int. 661. After the fact had been established that intelligible, articulate speech had been transmitted, was difficulty experienced in enlisting capital for the purpose of rendering the invention pecuniarily valuable?

Ans. I do not know, as I have never been connected with the commercial side of the telephone; I left that to my partners.

Cross-Int. 662. All the instruments illustrated in your answer to Question 122 are provided with means for changing the distance between the magnets and the diaphragm, except the liquid transmitter. That is so, is it not?

Ans. Yes. But there is no magnet at all in the case of the liquid transmitter.

Cross-Int. 663. Is the multiple-telegraph apparatus — current-interrupters and tuned-reed receivers — which you showed in operation at the Centennial Exhibition, shown in any cut or drawing which has been put in evidence in this cause?

Ans. The current-interrupters were substantially the same as the instrument shown in Figs. 1 and 2 of my application of February 25, 1875. The tuned-reed receivers were like those shown in Fig. 5 of my patent of March 7, 1876; and each receiver was provided with a vibratory circuit-breaker like that shown in Fig. 1 of my patent of June 6, 1876, No. 178,399, which operated an ordinary Morse sounder in a local circuit, in the manner shown in Fig. 2 of that patent — No. 178,399.

Cross-Int. 664. In your answer to Question 131, you say that with the iron-box instrument as a transmitter, and using the membrane telephone as a receiver, speech-sounds were transmitted. Do you mean by "speech-sounds" that articulate, intelligible speech was transmitted when the iron-box instrument was used as a transmitter?

Ans. I do not remember at the present time whether the articulate speech transmitted was intelligible or not, but I am inclined to think it was; but the sounds produced were much fainter than when the membrane telephone was used as a transmitter, and the iron-box as a receiver. Of course I am speaking of the actual iron-box instrument which was exhibited at the Centennial. The iron-box instrument of larger diameter, made subsequently, a duplicate of which was given to Sir William Thomson, was an admirable transmitter for speech.

Cross-Int. 665. In your answer to Question 132, you spoke of the iron or steel diaphragm of the iron-box instrument known as the

Centennial Iron-Box Receiver. As a matter of fact, was the diaphragm of iron or steel?

Ans. Sometimes of one material, sometimes of the other. I do not remember now which was the material used at the Centennial, but am inclined to think it was steel. The original diaphragm was of steel.

Cross-Int. 666. Did it make any practical difference in the operation of the instrument whether the diaphragm was of iron or steel?

Ans. The steel diaphragm would become permanently magnetic, and then worked better, if I remember rightly, with the current in one direction through the coils of the electro-magnet, than if it was in the other direction. I do not think it made very much difference, however, whether the diaphragm was of iron or steel.

Cross-Int. 667. What I was trying to get at was the practical value of iron and steel when used as the diaphragm of the iron-box receiver. Were the results obtained better when the diaphragm was constructed of steel, than when the diaphragm was constructed of iron?

Ans. I do not think there was very much difference, at least when the current was the right way through the electro-magnet for the steel diaphragm.

Cross-Int. 668. In your answer to Question 134, you say :

“This sheet of Tagger’s iron was used in quite a number of experiments, both for receiving and transmitting speech, during the month of July, 1876; sometimes with and sometimes without a battery upon the circuit.”

What were the results of the experiments without a battery upon the circuit, during the month of July, 1876.

Ans. We obtained audible effects through enormous resistances.

Cross-Int. 669. Did you obtain intelligible, articulate speech when the sheet of Tagger’s iron was used for receiving and transmitting speech, without a battery in the circuit, in the month of July, 1876?

Ans. That is my recollection. At that time we had advanced beyond the point of merely getting intelligible speech, and the main object of our experiments was to get good working results on long circuits. We certainly obtained intelligible, articulate speech, with-

out a battery, in July, 1876. I cannot say how far it was intelligible when an enormous resistance was introduced, but audible effects were obtained with resistances equivalent to hundreds of miles of telegraph wire.

Cross-Int. 670. I understand you to mean, in your answer to Question 134, by the words "without a battery in circuit," that you substituted an electro-magnet with permanently-magnetized cores, in the transmitting instrument, for an electro-magnet worked by a battery. That is so, is it not?

Ans. I did substitute an electro-magnet with permanently-magnetized cores for the electro-magnet with soft-iron cores, in similar experiments made in July, 1875, but I did not allude to these in my answer to Question 134. Perhaps I should rather say that I substituted an electro-magnet with permanently-magnetized steel cores, for one with soft-iron cores, in similar experiments in July, 1875; but I did not intend to allude to these here. Of course, in both cases, the cores were, in reality, permanently magnetic, but the soft-iron cores retained a very much feebler magnetic condition than the permanently-magnetized steel cores; and I have been accustomed to speak of the permanent magnetism retained by the soft-iron core as "residual magnetism." This is the same thing as permanent magnetism; it is only a question of degree, not of kind of magnetical condition.

Cross-Int. 671. The exact language used in your answer to Question 134, to which I referred, is as follows:

"This sheet of Tagger's iron was used in quite a number of experiments, both for receiving and transmitting speech, during the month of July, 1876; sometimes with and sometimes without a battery upon the circuit."

I understand from your last answer that when the battery was upon the circuit, the experiments of July, 1876, might have been conducted in a variety of ways. In the first place, the electro-magnets in the receiving and transmitting instruments might have been allowed to remain as they were when the battery was used, and the experiment might have been conducted on that basis. Secondly, permanently-magnetized steel cores might have been substituted for the soft-iron cores of the transmitting instrument, and

the experiment conducted on that basis. Thirdly, permanently-magnetized steel cores might have been substituted for the soft-iron cores of both the receiving and transmitting instruments, and the experiment conducted on that basis. Fourthly, permanently-magnetized steel cores might have been substituted for the soft-iron cores of the receiving instrument, and the experiment conducted on that basis. What I want to find out is what you mean in that answer by the words "without a battery upon the circuit;" and in order that I may understand what you did mean, will you state whether either or all of the experiments to which I have referred were conducted in the month of July, 1876, when the sheet of Tagger's iron was used either for a receiving instrument, transmitting instrument, or both.

Ans. When I gave my last preceding answer, I did not notice that my answer to Interrogatory 134 referred to experiments with the sheet of Tagger's iron during the whole month of July, 1876. I will therefore, modify that answer, and say that my answer to Interrogatory 134 did refer to experiments with permanently-magnetized steel cores, as well as to experiments without. All of the experiments to which you refer in the present question were conducted in the month of July, 1876, with possibly the exception of the third. I know that permanently-magnetized steel cores were used in the transmitter, as in your second plan; and also in the receiver, as in your fourth plan; but cannot be sure that they were used at both ends simultaneously, in July, 1876, and am inclined to think that they were not.

Cross-Int. 672. The magnet with permanently-magnetized cores, referred to in your last answer, was, I believe, the one that was constructed for you by Mr. Williams, and is referred to particularly in your answer to Question 147. That is so, is it not?

Ans. Yes. That is the one I alluded to as having permanently-magnetized steel cores.

Cross-Int. 673. And that was the only magnet having permanently-magnetized steel cores with which you experimented during the month of July, 1876, was it not?

Ans. I think so.

Cross-Int. 674. And this magnet with permanently-magnetized

steel cores, referred to in your last answer, was the first magnet of that kind that Mr. Williams had ever made for you. Is that so?

Ans. Yes. The first electro-magnet with permanently-magnetized steel cores. I before testified that I used a U-shaped permanent magnet in June, 1875, of steel, which was vibrated like a tuning-fork in front of the poles of an electro-magnet.

Cross-Int. 675. When did you next have an electro-magnet with permanently-magnetized steel cores constructed after that which was made for you by Mr. Williams, and referred to by you in your answer to Question 147?

Ans. I think the next was constructed immediately after an experiment made on the Cambridge time-line between Boston and Cambridge, with the permanent steel magnet already referred to. I do not remember the exact date, but I think it was within a very few days after the opening of the line between Exeter Place and the Cambridge Observatory. I find from my answer to Interrogatory 167 that the line connecting my laboratory in Exeter Place with Cambridge Observatory was completed on the 10th of November, 1876.

Cross-Int. 676. Did the telephone instruments made or used by you during the period mentioned in Question 143 differ in any respect, except in the resistance of the coils of the electro-magnets, from those exhibited at the Centennial Exhibition?

Ans. Certainly. For example, I used in a transmitter a membrane carrying a patch of iron almost as large in diameter as the membrane itself. I also used a completely metallic diaphragm of Tagger's iron, both as a transmitter and receiver, and combined this with an electro-magnet having permanently-magnetized cores of steel, etc.

Cross-Int. 677. In your answer to Question 145 you refer to Figs. 24 and 25 of your lecture delivered before the Society of Telegraph Engineers, October 31, 1877, in London, and state that the instruments shown in those figures had been pictured in public prints in England before you gave the lecture referred to. What public prints did you refer to?

Ans. I referred to published descriptions relating to Sir William Thomson's address before the British Association for the Advance-

ment of Science, in September, 1876; for example, an article in "Engineering," published December 22, 1876, entitled "Bell's Articulating Telephone," which is in evidence in this case, is illustrated by drawings substantially similar to Figs. 24 and 25* of my London lecture. It will be observed that in both cases the iron-box receiver is shown with the lid tilted up on one side.

Cross-Int. 678. You were asked by Question 147, when you first constructed an electro-magnet with permanently-magnetized cores and used the same in an electric-speaking telephone, and you replied that you gave orders for the construction of such a telephone in the early part of July, 1876, probably very shortly after your letter of July 2, 1876, to Mr. William Hubbard, and you said that you fix that date by an entry made in Mr. Williams's account book on the 15th of July, 1876, giving the charge for making a two-pole electro-magnet with permanently-magnetized cores. Have you any other way of fixing the date when you gave orders for the construction of that telephone, excepting the charge contained in Mr. Williams's books for the magnet?

Ans. The charge contained in Mr. Williams's book for the magnet, namely, July 15, 1876, indicates that the magnet was completed at that date. Orders for the construction of the instrument were, of course, given before that. In my letter to Mr. William Hubbard of July 2, 1876, I said: "I am sure by substituting a *permanent magnet* for the pole of the electro-magnet, I could work it *without a battery at all*." My recollection is that I gave orders for the construction of the permanent magnet referred to in Mr. Williams's charge, immediately after writing that letter to Mr. Hubbard, or at least very shortly after. The orders for the construction were, therefore, given between July 2d and July 15th, 1876, and the telephone containing an electro-magnet with permanently-magnetized steel cores was completed on or about the fifteenth day of July, 1876, the date of Mr. Williams's charge for the magnet.

Cross-Int. 679. Do you mean by your last answer that you already had in your possession telephone instruments provided with magnets having soft-iron cores, and that when the magnet having permanently-magnetized steel cores was constructed by Mr. Williams,

* See page 115.

it was only necessary to make the change of substituting the magnet having steel cores, for those before used having soft-iron cores?

Ans. Yes.

Cross-Int. 680. Then, when you state in reply to Question 147, "I gave orders for the construction of such a telephone in the early part of July, 1876," you mean, do you, that you gave orders for the construction of an 'electro-magnet having permanently-magnetized steel cores, with instructions that such magnet should be substituted in telephones before used by you having soft-iron cores?

Ans. My recollection is that I gave orders for the construction of a telephone containing an electro-magnet with permanently-magnetized steel cores, and as they did not have such an electro-magnet in Williams's place, they had to make it. The order for the construction of the telephone was given shortly after the 2d of July, and the telephone was completed on or about the 15th of July, 1876.

Cross-Int. 681. I wish you would describe this telephone mentioned in your last answer, that was completed on or about the 15th of July, and point out those parts of it which were new, and those parts of it which had been before in your possession.

Ans. If I remember rightly, the telephone referred to was similar to the membrane telephone given to Sir William Thomson. An electro-magnet with permanently-magnetized steel cores was used instead of one with soft-iron cores. I had all the parts, excepting the electro-magnet with steel cores, at the time the order for construction was given.

Cross-Int. 682. And have you any way of fixing the date when the telephone instrument referred to in your last answer, having permanently-magnetized steel cores, was first used as a transmitter or as a receiver?

Ans. Yes. I know that it was used both as a transmitter and receiver of articulate speech immediately after the construction of the electro-magnet with permanently-magnetized steel cores. The charge in Mr. Williams's book shows that this electro-magnet was completed on or about the 15th of July, 1876.

Cross-Int. 683. Then, if I understand you correctly, the charge in Mr. Williams's book informs you of the fact that the magnet

having steel cores was finished July 15, 1876; and your unaided recollection prompts you to say that a telephone having that magnet in it was used immediately afterward. That is so, is it not?

Ans. Not quite. The charge shows that on the 15th of July, 1876, the electro-magnet with permanently-magnetized cores was in existence, and its parts had been measured. It is perfectly possible that it might have been completed before that date, at any time between the 2d of July and the 15th. My unaided recollection entitles me to assert that a telephone having that magnet in it was used immediately after the construction of the magnet. If this date was earlier than July 15th, then the telephone was completed earlier.

Cross-Int. 684. I understood you to say in answer to Question 147, that you had no doubt that the permanent-magnet telephone was used on or about the 15th of July, 1876, as a receiver, and the iron-box instrument as a transmitter, because it was usually your custom to try the reversibility of the instruments. I understand from this answer that you fix that fact from the recollection of the circumstance that it was your custom to try the reversibility of the instruments. Am I correct in forming this conclusion?

Ans. Yes; it was so much my custom in those days, that I do not remember ever talking to an instrument, without also listening to the instrument to see if anything could be heard from the other end.

Cross-Int. 685. You also say in your answer to Question 147:

“ The permanent-magnet telephone was also undoubtedly used in connection with another membrane telephone, instead of the iron-box instrument, and experiments made with it, both as a transmitter and receiver.”

I gather from your mode of expression, that you also fix this fact from a recollection of the general nature of the experiments made by you, and not because you have any positive recollection of any occasion when the permanent-magnet telephone was used in connection with another membrane telephone, instead of the iron-box instrument. Is my conclusion correct?

Ans. My recollection warrants me in asserting positively that immediately after the construction of the electro-magnet with permanently-magnetized steel cores, it was used in combination with

the different instrumentalities I had in my possession, both as a transmitter and receiver of speech ; and this is the basis of the statement quoted.

Cross-Int. 686. Have you any way of aiding this naked recollection in regard to this matter — any contemporaneous memoranda, or any recollection of the persons present at the time the experiments occurred?

Ans. Yes. I remember the fact of the experiments being made immediately after the construction of the electro-magnet with permanently-magnetized steel cores ; and the charge from Mr. Williams's book for making the electro-magnet is a contemporaneous record, giving approximately the date of the experiments. Mr. Thomas A. Watson assisted me in most of the experiments referred to. I have also a recollection that a young man named Edward Wilson assisted me in some of them. I think also that some contemporaneous record of some of the experiments made about that time — July, 1876 — exists and has been produced in evidence in some of the lawsuits in which my patents have been involved. I cannot recall, however, exactly the nature of the experiments noted in these memoranda, without consulting the notes themselves.

Cross-Int. 687. Having reference to your statement that Mr. Watson assisted you in most of the experiments, does your recollection enable you to specify just what experiments he did assist you in, and just what experiments were conducted without his assistance?

Ans. Mr. Watson superintended the construction of the apparatus, and, as a general rule, when we tried experiments, he was at one end of the circuit, and I at the other. It was sometimes convenient for me, however, to employ some friend to shout, and speak, and listen at the other end of the circuit, instead of troubling Mr. Watson and taking him from his work. I think Mr. Edward Wilson sometimes assisted me at that time — July, 1876 — in this way, and other friends occasionally helped me in the same manner.

Cross-Int. 688. In your answer to the same Question 147, you use the following language :

"I cannot now recall the details of all these experiments, but I know that speech sounds were transmitted and received by means of this permanently-magnetized electro magnet in July, 1876."

Are you able, at the present time, to recall the specific details of any one particular experiment in which speech sounds were transmitted and received by means of the permanently-magnetized electro-magnet, in July, 1876; and state just who was present at the time the experiment occurred?

Ans. I have a general recollection of so many experiments in which speech sounds were transmitted and received by means of this electro-magnet with permanently-magnetized steel cores, in July, 1876, that they are all mixed up together. I cannot now pretend to separate the one experiment from the other, and give the details of particular experiments, and state who were present. My recollection, however, warrants me in asserting positively that speech sounds were transmitted and received by means of that magnet in July, 1876.

Cross-Int. 689. In your answer to Question 149, you use the following language in relation to membrane diaphragms carrying patches of iron or steel glued to them as armatures :

“The patches were not all of the same size or shape as those used in the Centennial instruments. I had a variety of iron or steel patches of different sizes, from a piece half an inch in diameter up to a sheet of iron or steel almost as large in diameter as the membrane to which it was attached.”

Will you please give the result of your experiments with patches of different size, stating which gave the best result?

Ans. The larger the diameter of the patch, the better the result seemed to be; and the best results were obtained with a patch almost as large in diameter as the membrane to which it was attached.

Cross-Int. 690. You say in your answer to Question 154, that during the first or second week of August, 1876, another notable event in the history of the electric speaking telephone occurred; and that articulate speech was, for the first time, transmitted and received between places that were separated by miles of space. As nearly as you recollect, what was the greatest distance between the transmitter and receiver in any prior experiment?

Ans. I am sure I cannot say. It certainly could not have exceeded a very small fraction of a mile.

Cross-Int. 691. In your answer to the same question, you say that you telegraphed to Brantford over another line, and asked Mr.

Griffin to substitute another electro-magnet with coils of high resistance for the low-resistance one he was using; and that while he was doing this, you made a similar change in the coil of the iron-box receiver, and that the experiments were then resumed; that the disturbing noises still continued, but the vocal sounds, instead of being faint and far away, became so loud and clear that familiar sentences were understood; and that you could even recognize the voices of the different speakers. Was it simply the substitution of coils of high resistance which enabled you to understand familiar sentences, as stated?

Ans. It was the increased loudness of the sounds that enabled me to understand them.

Cross-Int. 692. What caused the increased loudness of the sounds?

Ans. The substitution of high-resistance coils for the low-resistance coils. I mean the substitution of coils having many turns of fine wire for coarser coils having less turns.

Cross-Int. 693. You say, in the same answer, that one voice sounded so like your father's that you telegraphed to Brantford to ascertain whether it could possibly be his. From the fact that you used the telegraph, I understand that you were unable to use the telephone for the transmission of speech from Paris to Brantford. Is that so?

Ans. I did not make the attempt, as the receiving instrument I had in Paris was not well fitted to act as a transmitter with the membrane telephone at Brantford as a receiver.

Cross-Int. 694. Why was the receiving instrument that you had at Paris not fitted to act as a transmitter with the membrane telephone at Brantford as a receiver?

Ans. I think the trouble was chiefly with the membrane telephone, which seemed to act better as a transmitter than as a receiver.

Cross-Int. 695. Is your knowledge of the subject sufficient to enable you to state the reason for the facts stated in your last answer? If so, please give the reason.

Ans. My knowledge is derived from experiment, and I simply know that, as a matter of fact, the membrane telephone used in the experiments between Brantford and Paris seemed to act better as a

transmitter than as a receiver. The membrane was specially arranged to be thrown into vibration by the voice, but the construction of the apparatus precluded the possibility of getting the ear into close contact with the metallic patch carried by the membrane.

Cross-Int. 696. How near could the ear be placed to the metallic patch carried by the membrane?

Ans. By removing the triple mouth-piece it might perhaps be possible to bring the ear within about an inch of the membrane. In the apparatus as used at Brantford, however, an ear applied to one of the mouth-pieces would be many inches away from the membrane.

Cross-Int. 697. Having reference to these experiments in Canada, referred to in the same answer, had you made any attempt to take out a Canadian patent for any of your inventions prior to these experiments?

Ans. I had made arrangements with the Honorable George Brown and his brother to take out patents in foreign countries, and Canada was understood to come within this agreement, so far as I recollect.

Cross-Int. 698. In carrying out your agreement with the Honorable George Brown and his brother, did you ever prepare any application for a Canadian patent?

Ans. I gave the Honorable George Brown a copy of the specifications that were prepared for the United States Patent Office, and he was to see to the preparation of the applications for patents in foreign countries.

Cross-Int. 699. If I understand your last answer correctly, you gave the Honorable George Brown a copy of the United States application, and from that he was to prepare or cause to be prepared a Canadian application, which was to be forwarded to you for execution and oath, as provided by Canadian law and the regulations of the Canadian Patent Office. Is that so?

Ans. My recollection is that the only country specifically agreed upon was Great Britain, and that it was left to the Honorable George Brown to decide in what other foreign countries he would take out patents.

Cross-Int. 700. Were you at any time ever called upon to

make oath to an application for letters patent for the Dominion of Canada?

Ans. Not under my agreement with the Honorable George Brown and his brother. No patent was taken out by them on my behalf in any country whatever.

Cross-Int. 701. My last question was not intended to be limited in any way. Please answer it with this understanding.

Ans. There was a patent taken out in Canada, but I do not remember the details of it. I suppose I made oath to it, but remember nothing about it at the present moment. If it is a matter of importance I shall be happy to make inquiries and let you know the facts.

Cross-Int. 702. Was more than one patent taken out in Canada?

Ans. I am sure I cannot say from memory alone.

Cross-Int. 703. Do you recollect whether the subject-matter of the patent taken out in Canada was the same as the subject-matter of your patent of March 7, 1876?

Ans. Yes; that subject-matter was included if I remember rightly.

Cross-Int. 704. You state, in answer to Question 157, that about the 11th of September, 1876, Mr. Watson was employed, and paid for a portion of his time, and given an interest in the inventions he was assisting to put into commercial use. What interest was given to Mr. Watson, and were the inventions he was assisting to put into commercial use those described and claimed in your patent of March 7, 1876, and of January 30, 1877?

Ans. If I remember rightly he was given a one-tenth interest. The inventions described and claimed in my patent of March 7, 1876, and of January 30, 1877, were included among those he was to assist me in putting into commercial use. At least that is my recollection.

Cross-Int. 705. Was that agreement ever carried out, and did Mr. Watson receive a one-tenth interest in the inventions mentioned in your last answer?

Ans. I believe so.

Cross-Int. 706. I understand you to say, in answer to Question 158, that during the latter part of September, 1876, the pecuniary

value of the speaking telephone inventions was not fully appreciated, although the invention was looked upon as a very wonderful thing. In using the words "fully appreciated," did you intend to apply them to Messrs. Sanders and Hubbard, or to the public generally?

Ans. To the public generally, including Messrs. Sanders and Hubbard.

Cross-Int. 707. You say in the same answer that your associates, Messrs. Sanders and Hubbard, were anxious that considerable attention should be devoted also to the multiple-telegraph inventions, which had been somewhat neglected. Did those gentlemen at that time look upon the multiple telegraph as being more valuable than the speaking telephone?

Ans. I think they did.

Cross-Int. 708. Has the multiple telegraph, referred to in the same answer, ever gone into commercial use to any extent?

Ans. No.

Cross-Int. 709. In your answer to Question 163, you say that when you took up the subject again in the beginning of October, 1876, you determined to repeat the experiments with membrane telephones, each carrying a sheet of iron almost as large in diameter as the membrane to which it was attached, and to construct and test telephones with metallic diaphragms alone; and that, in accordance with this decision, Mr. Watson arranged two single-pole electro-magnet membrane telephones with straining-rings and supporting-rings made of castings from the same patterns as those of the Centennial membrane telephones, and that upon each membrane he glued a thin circular sheet of iron almost as large in diameter as the membrane itself; that no mouth-piece was employed, and the electro-magnet was presented to the opposite side of the membrane to that shown in the Centennial instruments, and with its pole next the membrane inside the supporting-ring. Are any of these instruments still in existence, or is any drawing of them still in existence?

Ans. I think it is very probable that the original instruments are in existence, among the models in the possession of the American Bell Telephone Company, but I cannot say positively at the present moment. I think drawings or diagrams also are in existence.

Cross-Int. 710. But these instruments, or drawings thereof, have not been produced in this case during the taking of your testimony, have they?

Ans. No.

Cross-Int. 711. In your answer to the same question, you say that in an experiment on the 9th of October, 1876, actual conversation, backwards and forwards, upon the same line, and by the same instruments reciprocally used, was successfully carried on for the first time upon a real line of miles in length. When was actual conversation backwards and forwards, upon the same line, and by the same instruments reciprocally used, successfully carried on, on a line of any length?

Ans. The instruments constructed in June and July, 1875, were capable of reciprocal use; and in the case of the membrane telephones made and used in March, April and May, 1876, conversation was successfully carried on by the instruments reciprocally used, upon short circuits, as described in paragraph 12 of my lecture before the American Academy of Arts and Sciences, May 10, 1876.

Cross-Int. 712. Please describe exactly the sense in which you use the words "reciprocally used" in your last answer?

Ans. I mean that each telephone instrument was used alternately as a transmitter and receiver.

Cross-Int. 713. In your answer to Question 166, you say that immediately after the Walworth line experiments, you were using sheets of iron or steel of sufficient thickness to support their own weight when held horizontally by one edge. How did the thickness of these sheets compare with the thickness of a sheet of the ordinary tinned-iron plate of commerce?

Ans. I should say the thickness was about the same, or perhaps a little greater.

Cross-Int. 714. Are any of these sheets of iron or steel, referred to in your last answer, now in existence?

Ans. I think so. If not the identical sheets, certainly similar sheets.

Cross-Int. 715. But they have not been produced during the taking of your testimony in this cause, have they?

Ans. No.

Cross-Int. 716. You also say, in the same answer, that about the 19th or 20th of October, box telephones were constructed, each containing a single-pole electro-magnet; and that a sheet of iron or steel formed one side of the box, and the electro-magnet inside was arranged with its pole in close proximity to the centre of the metallic diaphragm; that each box was rectangular in shape, and at first was provided with a hole on the top, into which you spoke. Is this apparatus in existence at the present time?

Ans. My recollection is that, after some modifications had been made, one of these instruments was used as a model for my patent of January 30, 1877; and it is, I presume, still in existence.

Cross-Int. 717. Do you mean by your last answer, that the instrument was deposited as a model at the United States Patent Office, and used at the United States Patent Office as such?

Ans. That is my meaning.

Cross-Int. 718. It appears from Question 169 that the provisional specification of your English patent contained, among other things, the following paragraph:

“Or the coils shown in Figures 24, 25, and 26 may be induction coils of usual construction, local batteries being placed in circuit with the primary wires so as to magnetize the soft iron cores of the coils.”

When did you first construct or use a telephone in which the coils were induction coils of the usual construction, and in which local batteries were placed in circuit with the primary wires so as to magnetize the soft-iron cores of the coils?

Ans. In June, 1875, I constructed telephonic apparatus consisting of a tuned reed like that shown in Fig. 5 of my patent of March 7, 1876, in which a local battery was placed in circuit with a primary coil surrounding the uncovered leg of Fig. 5 so as to magnetize the soft-iron core of the covered leg, the coil of which constituted a secondary circuit. I am not sure when I first used an induction coil in a speaking telephone, but I know that I did so on or about the 10th of November, 1876.

Cross-Int. 719. Please describe this experiment of the 10th of November, 1876, if you have not already done so; and if you have done so, please refer to that part of the testimony where the experiment is described.

Ans. On or about the 10th of November, 1876, I made a number of experiments in inducing effects from one circuit into another. I do not now remember whether I used upon that occasion an induction coil of usual construction, but my experiments led me to conclude that such a coil would work very well. I remember one experiment made at that time, in which two single-pole electro-magnets were placed face to face. The coil of one of these was connected in circuit with a metallic-diaphragm telephone and with a local battery, and the coil of the other was placed in an independent circuit with another telephone which was used as a receiver, without any battery upon the circuit. Upon speaking to the telephone connected with the battery circuit, speech sounds were clearly reproduced by the receiving telephone which was in the circuit which contained no battery; and considerable resistance could be introduced into that circuit without materially affecting the audible results. I am inclined to think also, that about the 10th of November, 1876, I tried dividing the coil of the single-pole electro-magnet used, into halves, forming two separate coils surrounding a single straight rod of iron. A battery was connected with one of these coils to magnetize the rod, and the other coil was connected in circuit with the receiving telephone without any battery. I cannot be quite sure, at this date, whether that was tried upon the 10th of November, 1876, or not, but I think it was. If not at that time, it was tried subsequently, not long afterwards. The other experiment narrated, I feel confident was tried upon that day.

Cross-Int. 720. You say, in answer to Question 169, that within a day or two after the 10th of November, 1876, you tried the experiment between Boston and Cambridge Observatory, employing upon the occasion the same electro-magnet with permanently-magnetized cores which had been made for you by Mr. Charles Williams on or about the 15th of July, 1876; and that the telephone containing this electro-magnet was at the Boston end of the line, and was operated successfully without any battery upon the circuit, both as a transmitter and receiver of articulate speech. I understand from this statement, that in this experiment, you had and used but one electro-magnet with permanently-magnetized cores, and that that magnet was the one made for you by Mr. Charles Williams on or about the

15th of July, 1876. Is my understanding of your testimony correct?

Ans. Yes. Upon that occasion I had but one with permanently-magnetized steel cores; the other instrument had soft-iron cores, which were permanently magnetic in a slight degree, on account of residual magnetism.

Cross-Int. 721. Then, if I understand your testimony correctly, the result of this experiment was the same as if an electro-magnet with permanently-magnetized cores had been used in the transmitting instrument and also in the receiving instrument at the same time, for the same message. Is that so?

Ans. Yes. The same in kind, but not in degree. In the experiment as actually tried, the cores of both instruments were in reality permanently magnetized, but of course the permanent magnetism retained by the soft-iron cores was very much less than if the cores had been made of steel; the audible effects produced were, therefore, less than if both instruments had contained steel cores. In the actual experiment referred to, only one of them had steel cores.

Cross-Int. 722. How was it with the apparatus shown in Fig. 7 of your patent of March 7, 1876, in case a battery was not used; were the cores of both the instruments permanently magnetized?

Ans. In a slight degree, due to residual magnetism. Under such circumstances, the operation of the apparatus without any battery would be due to permanent magnetism in the cores and attached parts. It is more usual to call this permanent magnetism *residual* magnetism, but it is the same thing under a different name.

Cross-Int. 723. Then the difference between the apparatus shown in Fig. 7 of your patent of March 7, 1876, in case a battery is not used, and the apparatus used in your experiments a day or two after the 10th of November, 1876, is a difference of degree, and not a difference of principle, is it?

Ans. There is a great difference between the instrumentalities employed, but no substantial difference in the mode of operation. In regard to the experiment between Boston and the Cambridge Observatory, made a day or two after the 10th of November, 1876, and referred to in my answer to Interrogatory 169, an electro-magnet was employed with permanently-magnetized steel cores, so that the

magnetic condition of each core was very much greater than that of the apparatus shown in Fig. 7 of my patent of March 7, 1876, when a battery was not used. A metallic diaphragm also was employed, which took the place of both the armature and membrane shown in Fig. 7 of my patent of March 7, 1876. This diaphragm-armature constituted, I think, an important difference in the construction of the apparatus.

Cross-Int. 724. You mean by your last answer, do you, that the electrical mode of operation of the apparatus shown in Fig. 7 of your patent of March 7, 1876, when a battery is dispensed with, is substantially the same as the electrical mode of operation of the instruments used by you in the experiments a day or two after the tenth day of November, 1876. Is that so?

Ans. I think so.

Cross-Int. 725. You say, in answer to Question 176, that a multitude of experiments were made in December, 1876, with the object of ascertaining empirically the best arrangement of permanent magnet, plate-armature, coil and mouth-piece, for use upon long lines; and that for this purpose you would keep every element of your combination constant except one, and test the effect of variations of that element. For example, using a given permanent magnet and a given coil, you would try the effect of iron and steel plates of different diameters and thicknesses; again, using a given permanent magnet and a given plate-armature, you would vary the coil; and, using a given coil and a given plate, you would vary the permanent magnet employed: and that, having in this way obtained an idea of the best form of each element, you sought to combine these in a practical working telephone, also experimenting upon the best form of mouth-piece; and that the extent to which you had progressed in December, 1876, is shown in your patent No. 186,787, of January 30, 1877. To what extent are the results of these experiments as to the permanent magnet, coil, iron and steel plates of different diameters and thicknesses, set forth in your patent No. 186,787?

Ans. To this extent — that I have shown in my patent No. 186,787, of January 30, 1877, a combination of these elements

constituting a practical working telephone suitable for use for commercial purposes.

Cross-Int. 726. Is the result of your experiments in relation to iron and steel plates of different diameters and thicknesses set out in your patent referred to; if so, please designate the paragraph?

Ans. As the result of these experiments, I have shown in Figs. 1, 2 and 3 of my patent No. 186,787, and in the model filed with the application, a plate-armature of suitable diameter and thickness for use in a speaking telephone like that shown in my patent.

Cross-Int. 727. Why was it that a model was filed at the Patent Office as a part of the application upon which patent No. 186,787, of January 30, 1877, was issued?

Ans. I am sure I don't know, excepting that a model was accepted by the Commissioner of Patents.

Cross-Int. 728. Were you called upon by your attorneys to prepare and furnish that model?

Ans. I do not remember now. I took practical working instruments with me to Washington for the information of my solicitors; and I exhibited some of them publicly before the Philosophical Society. I only know that my solicitors filed one of the instruments, as a model, in the Patent Office.

Cross-Int. 729. Were these practical working instruments also tested before the examining officers of the Patent Office?

Ans. I don't remember any such tests at the present moment. There may have been, but I don't think there were.

Cross-Int. 730. I understand you to say, in answer to Question 182, that your application for patent No. 186,787, of January 30, 1877, was prepared in Washington, with the assistance of your patent solicitors, Messrs. Pollok & Bailey. Were the claims of that patent drawn in whole or in part by you, or were they prepared in whole or in part by your solicitors?

Ans. The 3rd claim was drawn by me; the others were prepared by my solicitors.

Cross-Int. 731. Was the specification of this patent No. 186,787 prepared by your solicitors from a draft furnished by you, or from oral instructions given by you?

Ans. Chiefly from oral instructions; but I think they had before

them a copy of the provisional specification of my English patent, filed December 9, 1876.

Cross-Int. 732. You speak, in answer to Question 183, of exhibiting your speaking telephones in operation before the members of the Philosophical Society of Washington, on the evening of January 13, 1877. When did you, or any one else, first exhibit or use a speaking telephone in the city of Washington?

Ans. I do not know of any exhibition or use of the speaking telephone in the city of Washington, before January, 1877, although, of course, there may have been such exhibition or use by others, without my knowledge.

Cross-Int. 733. In the record of the 116th meeting of the Philosophical Society of Washington, quoted in your answer to Question 184, the following paragraph occurs :

"Mr. Bell having spoken of the difficulty with such consonants as *p*, *t*, and *k*, Mr. Mason suggested that such an instrument when perfected might be used in analyzing linguistic sounds."

When did you first discover the difficulty with the consonants *p*, *t*, and *k*?

Ans. From the very first time intelligible speech was produced by the telephone. The defect still remains in the most perfect instruments, though it does not interfere with their commercial use.

Cross-Int. 734. Then it is a fact, is it not, that some sounds cannot be transmitted by the telephone, even in its most perfected form?

Ans. They can all be transmitted with substantial accuracy, sufficient for commercial purposes; although when you come to examine the matter scientifically, difficulties make their appearance.

Cross-Int. 735. Then, if I understand you correctly, in all telephones the sounds perceived by the ear at the receiver are at best imperfect imitations of those produced at the transmitter. Is that so?

Ans. Hardly imperfect imitations, for there is no difficulty in understanding what is said.

Cross-Int. 736. You say, in answer to Question 189, that while you cannot recall the character of all the apparatus employed on the 3d of December, 1876, you have the recollection that during the course of the experiments made on that day, telephones were used at

either end of the line, each of which had a metallic diaphragm of iron or steel in close proximity to the pole or poles of the electro-magnet, the core or cores of which were either themselves permanently magnetic or were rendered permanently magnetic by contact with the pole or poles of a permanent magnet. I gather from this that you do not now remember whether the cores were permanently magnetic themselves, or rendered permanently magnetic by contact with the pole or poles of a permanent magnet. Is my conclusion correct?

Ans. I remember that permanent magnets were employed; but as my impression is that we had in the laboratory both forms referred to, I cannot tell which was employed in the experiments between Boston and North Conway on the 3d of December, 1876; probably both were tried. I mean, that so far as I can recollect, we had in the laboratory permanent steel magnets in the shape of straight cylindrical rods, which could be used in place of the soft-iron core of an electro-magnet; and we also had permanent magnets with soft-iron pole-pieces attached. As we made very thorough tests of all the apparatus Mr. Watson could carry to North Conway, and with the special object, so far as I remember, of testing the operation of permanent-magnet telephones upon long lines without a battery, it is probable that both forms of magnet were tried. So many experiments, however, were made upon that occasion, that it is difficult for me to recall the details of any specific case. I can only assert that on the 3d of December, 1876, articulate speech was successfully transmitted between Boston and North Conway by means of permanent-magnet telephones without any battery upon the circuit, and that after that date, permanent magnets were habitually employed in the laboratory, in place of electro-magnets operated by a battery current.

Cross-Int. 737. I understand you to say, in your last answer, that on the 3d of December, 1876, you had permanent magnets, with soft-iron pole-pieces attached, in the "laboratory." To what laboratory did you thus refer?

Ans. I referred to the laboratory at No. 5, Exeter Place. I do not mean to assert positively that we had permanent magnets, with soft-iron pole-pieces attached, in the laboratory, on or before the third

day of December, 1876, though I think we had. If we did not have them on that day, we did have such magnets there very shortly afterwards.

Cross-Int. 738. This laboratory referred to in your last answer was your own private laboratory?

Ans. Yes.

Cross-Int. 739. Where did you get these permanent magnets with soft-iron pole-pieces attached, to which you have referred?

Ans. They were made for me.

Cross-Int. 740. Do you remember who made these permanent magnets with soft-iron pole-pieces attached; and when you first gave instructions for their manufacture?

Ans. They were made for me by Mr. Watson; I cannot tell the date with much accuracy; my impression is that it was either in November or in the early part of December, 1876; I am inclined to think November, but cannot be sure now.

Cross-Int. 741. Were these permanent magnets with soft-iron pole-pieces attached made at Mr. Williams's shop?

Ans. I do not know. Probably the permanent magnets were not made at Mr. Williams's shop, but were obtained elsewhere; the soft-iron pole-pieces were probably made there.

Cross-Int. 742. Where were you in the habit of obtaining electrical supplies about the 3d of December, 1876, including magnets?

Ans. I was in the habit of ordering anything I wanted from Mr. Williams.

Cross-Int. 743. Did you order from Mr. Williams exclusively electrical supplies, or did you patronize some other concern at times?

Ans. It was my custom to go to Mr. Williams for anything I wanted in the line of electrical supplies; but that did not prevent me from going elsewhere.

Cross-Int. 744. Do you now recollect any other concern or shop from which you purchased electrical supplies, except Mr. Williams's?

Ans. I do not remember the names of the places. I think there were at least two other places where I purchased little things occasionally. I made a practice of getting my electrical supplies as much as possible from Williams.

Cross-Int. 745. Are you able, after considering the matter, to

say definitely whether you did or did not obtain the permanent magnets to which the soft-iron pole-pieces were applied from Mr. Williams?

Ans. I am pretty sure we got these permanent magnets from Mr. Williams, though I do not suppose they were made in his workshop.

Cross-Int. 746. I wish you would be kind enough to describe fully and particularly the construction of the permanent magnets with soft-iron pole-pieces attached, referred to in your answer to Cross-question 736.

Ans. The permanent magnets I have in mind were of horse-shoe form, several inches in length. The legs were rectangular in cross section. A small single-pole electro-magnet having a soft-iron core was placed on the end of each pole, the soft-iron core making magnetic contact with the magnet. I do not remember just now whether the soft-iron cores were clamped to the ends of the magnet at first, or whether a screw-thread was cut in the end of each pole so that the pole-piece could be screwed to the magnet. Both of these means were used in the laboratory, but I don't remember which was used first.

Cross-Int. 747. When did you first see a permanent magnet with soft-iron pole-pieces attached thereto?

Ans. I am sure I don't know. It was years before 1876. I refer to Siemens's polarized relay.

Cross-Int. 748. And where, if ever, did you first read a printed description of a permanent magnet with soft-iron pole-pieces thereto attached?

Ans. I don't know, but I read a description of such a magnet in the work of the Comte du Moncel, already referred to, — *Exposé des Applications de l'Électricité* — in July, 1875.

Cross-Int. 749. Is a permanent magnet with soft-iron pole-pieces attached, described in any other printed publication to which you have referred on your direct or cross-examination in this cause, except the work of Du Moncel, mentioned in your last answer?

Ans. I do not remember at the present moment what other publications I have referred to in my testimony. If the matter is of

importance, I shall be glad to examine my testimony and give a more explicit answer.

Cross-Int. 750. Do you recollect whether or not a permanent magnet with soft-iron pole-pieces attached thereto, of the type known as the Hughes magnet, is described or illustrated in any of the printed publications which have been referred to by you during your examination?

Ans. Yes; the Hughes magnet is described and illustrated in the work of the Comte Du Moncel, already referred to — *Exposé des Applications de l'Électricité*.

Cross-Int. 751. Does the Hughes magnet described in Du Moncel's work, referred to in your last answer, differ in any respect from the magnet illustrated in Fig. 5 of the drawings of your patent No. 186,787?

Ans. I do not remember exactly what Du Moncel's description was, and I should have to see the work in order to answer the question explicitly. I may say, however, that there were differences. The most substantial difference is in the kind of armature employed.

The Hughes magnet, described by Du Moncel, was not combined with a plate of iron or steel, or other material capable of inductive action, which could be thrown into vibration by the movement of surrounding air, or by the attraction of the magnet. The magnet illustrated in Fig. 5 of the drawings of my patent No. 186,787, is shown and described in combination with such a diaphragm-armature, and forms a part of a speaking telephone.

Cross-Int. 752. I intended my last question simply to apply to the magnet shown in Fig. 5 of your patent No. 186,787, and I intend the following question also to have the same application. Fig. 5 referred to is described in the specification as follows:

"Another form of telephone for use without a battery is shown in Fig. 5, in which O is a compound permanent magnet, to the poles of which are affixed pole-pieces of soft iron P Q, surrounded by helices of insulated wire R S."

Do you recollect any differences between the magnet thus described and shown in Fig. 5, and the Hughes magnet described and illustrated in Du Moncel's work?

Ans. It depends upon how much you intend to include under

the term "magnet." If you consider the magnet separately from the combination of which it forms a constituent part, then I do not think there is any substantial difference between the magnet and attached pole-pieces of Fig. 5 of my patent No. 186,787, and the Hughes magnet described by Du Moncel. If, however, you consider an armature as forming a necessary part of a magnet (for a magnet has no function or use without an armature), then there is a vast difference between the magnet shown in Fig. 5 of my patent and the Hughes magnet described by Du Moncel. The combination shown in Fig. 5 constitutes a speaking telephone.

Cross-Int. 753. The fifth claim of your patent No. 186,787, of January 30, 1877, is as follows :

"5. The formation, in an electric telephone such as herein shown and described, of a magnet with a coil upon the end or ends of the magnet nearest the plate."

In view of the statement made in your last answer, will you be kind enough to state what you intended this fifth claim to cover at the time that you made oath to the application?

Ans. I intended it to cover the use of such a magnet in an electric-speaking telephone like that shown and described in my patent of January 30, 1877, No. 186,787, in which an armature is used consisting of a plate of iron or steel or other material capable of inductive action, which can be thrown into vibration by the movement of surrounding air or by the attraction of the magnet. I intended to claim a magnet with a coil upon the end or ends of the magnet nearest the plate, in a combination constituting an electric telephone such as is shown and described in the patent.

Cross-Int. 754. I understand from your last answer that although the word "combination" is not used in the fifth claim, you intended that claim to cover a combination of which a magnet with a coil upon the end or ends of the magnet nearest the plate was one of the elements. As a combination claim must, of course, consist of more than one element, will you please designate the other elements of this claim as intended by you when you made oath to the application?

Ans. The chief elements referred to in the claim are :

1. A diaphragm-armature consisting of a plate of iron or steel or other material capable of inductive action, so arranged as to be

capable of being thrown into sonorous vibration by sounds made in its neighborhood, or by the attraction of its magnet.

2. A magnet with a coil upon the end or ends of the magnet nearest the plate, the parts being combined together as described in the patent, so as to constitute an electric speaking telephone. I do not think I intended the claim to be a claim for the whole combination constituting an electric telephone, but a claim for a magnet with a coil upon the end or ends of the magnet nearest the plate, as an element of such a combination.

Cross-Int. 755. You have in your last answer, have you not, designated all the elements which you intended to claim in the combination?

Ans. I intended in the fifth claim to claim only one element of the combination, viz., a magnet with a coil upon the end or ends of the magnet nearest the plate.

Cross-Int. 756. I infer from your last answer that you understood at the time that you made oath to the application that you could claim one of the elements constituting a patentable combination. Was that your understanding at the time?

Ans. Not by itself, and apart from the combination, unless under such circumstances it constituted by itself a new and useful thing; but I understood at the time that if the *combination* constituted a new and useful invention, then, even if the parts were old, you could claim one of the parts as an element of the combination, although you could not claim it as distinct and separate from the combination.

Cross-Int. 757. I still fail to get a very clear idea of what you intended to claim in Claim 5. I understand that you intended it as a combination claim, and my understanding is that a combination claim must consist of a number of co-acting elements which produce a certain result; I should be glad, therefore, if you will be kind enough to state the result which you expected to attain by the instrumentalities set forth in this claim, and also all the elements constituting the combination which produce that result.

Ans. You understand, of course, that I did not myself draw this claim, and that I cannot pretend to give the proper construction to it; that is a matter for the courts to decide. I can only state what

I thought it meant at the time I made oath to the application. My understanding of it may have been right, or it may have been wrong; that is a matter for the courts to decide. The combination referred to in the claim, I understood, constituted an electric telephone; and the result I expected to attain by that combination was the transmission of articulate speech and other sounds by electrical means. The elements referred to in the claim as constituting the combination, are a diaphragm-armature of inductive material so arranged as to be set into sonorous vibration by the voice of a speaker, or by the varying attraction of an electro-magnet; and a magnet with a coil upon the end or ends of the magnet nearest the plate; the whole so arranged together as to constitute an electric telephone such as is shown and described in the patent No. 186,787. I did not intend in this fifth claim to claim the whole combination, but to claim as an element of that combination a magnet with a coil upon the end or ends of the magnet nearest the plate.

Cross-Int. 758. How did the invention which you intended to claim by the fifth claim at the time that you made oath to the invention, differ from the invention which you intended to claim by the eighth claim?

Ans. The fifth claim included more than the eighth claim. In the fifth claim, the word "magnet" covered, I believed, electro-magnets with soft-iron cores, as well as permanent magnets; but in the eighth claim, the word was limited to permanent magnets alone.

Cross-Int. 759. How did the invention which you intended to claim by the fifth claim at the time that you made oath to the application differ from the invention which you intended to claim by the third claim at the time that you made oath to the application?

Ans. In the third claim, I intended to claim a particular kind of armature in combination with an electro-magnet, to wit; a plate of iron or steel or other material capable of inductive action, which could be thrown into vibration by the movement of surrounding air, or by the attraction of the magnet. In the fifth claim, I intended to claim a particular kind of electro-magnet, to wit: a magnet with a coil upon the end or ends of the magnet nearest the plate, in a combination containing a diaphragm-armature or plate like that claimed

in the third claim ; the whole combination in both cases constituting an electric telephone.

Cross-Int. 760. I understand you to say, in answer to Question 243, that you took very great pains and care in the preparation of the specification and claims of your patent of March 7, 1876, with the object of defining as accurately as possible the invention which you knew you had originated, and which you believed then, and still believe, you were the first to have originated. In the preparation of that specification and those claims, with the object of defining as accurately as possible the invention which you had originated, what invention made by you did you specify or define in the first claim?

Ans. I specified in that claim a new and useful kind of electrical current which I termed an "undulatory" current, to wit : an electrical current moulded into undulations analogous to sound vibrations ; and a means of utilizing such a current for telegraphic purposes by causing it to set a receiving instrument into sonorous vibration. The invention specified in the claim is more fully set forth and defined in the body of the specification. I intended this claim to be a broad claim, to cover any system of telegraphy in which the receiver should be set into sonorous vibration by the action of an electrical current moulded into undulations corresponding to sonorous vibrations, substantially in the manner set forth in my patent of March 7, 1876, No. 174,465.

Cross-Int. 761. An undulatory current of electricity is, to use plain language, simply a current of constantly varying strength, is it not?

Ans. No. The electrical variations must correspond to sonorous vibrations. In the specification, I say that :

"Electrical undulations result from gradual changes of intensity exactly analogous to the changes in the density of air occasioned by simple pendulous vibrations. The electrical movement, like the aerial motion, can be represented by a sinusoidal curve or by the resultant of several sinusoidal curves."

Cross-Int. 762. In the preparation of the specification and claims of your patent of March 7, 1876, with the object of defining as accurately as possible the invention which you had originated, what

invention made by you did you specify or define in the second claim of that patent?

Ans. I specified a magneto-electric mode of producing electrical undulations like sound vibrations without any battery upon the circuit, by the sonorous vibration of a permanent magnet in front of an electro-magnetic coil forming part of the circuit. This mode is more fully described and defined in the body of the specification, and would be illustrated by Figs. 5 and 7 if the battery were omitted from the circuit, and the armatures of the electro-magnets were considered as permanently magnetic. I intended the claim to be a broad claim for a mode of inducing electrical undulations like sound vibrations upon a circuit containing no battery, by causing a body capable of inductive action to be thrown into sonorous vibration. The means specifically referred to in the claim are: 1. A permanent magnet; and, 2, An electro-magnetic coil forming part of a closed circuit; and I claim specifically the mode of inducing electrical undulations like sound vibrations by the sonorous vibration of one or both of these elements in the neighborhood of the other. I did not intend, however, to limit myself to the means specifically described, but intended that the claim should be broad enough to cover equivalent means. Indeed, I stated in the claim that instead of a permanent magnet, any body capable of inductive action might be used, and in the body of the specification, said:

“I include in the category of bodies capable of inductive action — brass, copper, and other metals, as well as iron and steel.”

Cross-Int. 763. Is there anything said in the body of the specification, in describing Figs 5 and 7, about omitting the battery from the circuit, or making the armature permanently magnetic?

Ans. In the body of the specification, I say:

“It has long been known that when a permanent magnet is caused to approach the pole of an electro-magnet a current of electricity is induced in the coils of the latter, and that when it is made to recede a current of opposite polarity to the first appears upon the wire. When, therefore, a permanent magnet is caused to vibrate in front of the pole of an electro-magnet an undulatory current of electricity is induced in the coils of the electro-magnet, the undulations of which correspond, in rapidity of succession, to the vibrations of the magnet, in polarity to the direction of its motion, and in intensity to the amplitude of its vibration.”

This paragraph is illustrated both by Figs. 5 and 7, wherein equivalent means are shown of producing the magnetic condition required. For example, in reference to Fig. 5, I say :

“When the instrument A is placed in a voltaic circuit, *g b e f g*, the armature *c* becomes magnetic, and the polarity of its free end is opposed to that of the magnet underneath,” etc.

Cross-Int. 764. In what part of the body of the specification is the invention which you intended to specify and define by Claim 2 set forth in such a way that a person skilled in the art could make and use the invention claimed?

Ans. I have no doubt that anyone skilled in the art who reads the specification as a whole, will have no difficulty in making and using the invention specified and defined by Claim 2. He will be specially aided in this by the paragraphs I have quoted in my last preceding answer, and by the diagrams shown in Figs. 5 and 7, and the descriptions thereof in the body of the specification.

Cross-Int. 765. Are there any other paragraphs in the body of the specification, except those referred to in your last answer, which would specially aid one skilled in the art in making the invention which you intended to specify and define in Claim 2?

Ans. Certainly. All the paragraphs are so related together that the reading of the whole specification would aid materially in elucidating the meaning of any part of it.

Cross-Int. 766. How does the invention which you intended to specify and define by Claim 2, differ from the invention which you intended to specify and define by Claim 1?

Ans. The first claim was intended to be a broad claim for the use, in systems of telegraphy employing receivers that are electrically set in sonorous vibration, of what I term an “undulatory” current of electricity; that is, a current in which electrical oscillations or vibrations or undulations are produced, analogous to sound vibrations — quite independently of the mode of producing these undulations.

In Claim 2, I claim a particular mode of producing such undulations, viz, a magneto-electric mode, without any battery upon the circuit.

Cross-Int. 767. In which of the figures of the drawings of the

patent is the invention which you intended to specify and define in Claim 1 shown?

Ans. In Figs. 5, 6 and 7.

Cross-Int. 768. In Claim 2 the following language is used:

"2. The combination, substantially as set forth, of a permanent magnet or other body capable of inductive action, with a closed circuit, so that the vibration of the one shall occasion electrical undulations in the other, or in itself."

Please state what particular meaning you intended to give to the words "or in itself," as thus used.

Ans. If the permanent magnet be stationary, and the closed circuit — in the shape, for example, of a helix of wire — be thrown into sonorous vibration in the neighborhood of the permanent magnet, electrical undulations will appear in the vibrating coil itself.

Cross-Int. 769. Is there any such apparatus as that designated by you in your last answer, illustrated in the drawings of the specification?

Ans. Figs. 5 and 7 illustrate an equivalent means of producing electrical undulations, in which the coil is stationary, and in which the vibratory part of the apparatus occasions the sonorous vibration of the body capable of inductive action. Let the body capable of inductive action be stationary, and attach the coil to the vibratory part of the apparatus, then the drawings of Figs. 5 and 7 will illustrate such an apparatus as that inquired about.

Cross-Int. 770. Would such an apparatus as that described in your last answer, in which the coils were attached to the vibratory part of the apparatus, be operative to produce any useful result?

Ans. Certainly.

Cross-Int. 771. And do you mean that the attachment of the coils to the vibratory part of the apparatus would not interfere with the vibrations of the vibratory armature *c*?

Ans. In such a case there would be no vibratory armature at all, for the armature would be the stationary part of the apparatus. In the case of Fig. 5, the coil would be attached to a free reed blown by wind, and would not necessarily interfere with the free vibration of the reed. It would simply load the reed, and thus cause it to have a somewhat lower pitch. In the case of Fig. 7, the coil would

be attached directly to the membrane. In this case, the membrane would be loaded at the centre with a coil in place of the armature, and if the weights were equal, the apparatus would work as well in the one case as in the other. The loading of the membrane with a coil would not necessarily interfere with the successful operation of the apparatus in transmitting speech. I know this from experience, as I have made a telephone of this kind. I may say, therefore, both in regard to Fig. 5 and Fig. 7, that the attachment of a coil to the vibratory part of the apparatus would not necessarily interfere with the operation of the apparatus for the purposes specified in the patent.

Cross-Int. 772. Was an apparatus similar to that which you have imagined in your last answer constructed by you prior to the issue of your patent of March 7, 1876?

Ans. No. It was imagined prior to the issue of the patent, and constructed afterwards.

Cross-Int. 773. In using the language in the second claim :

"The combination, substantially as set forth, of a permanent magnet or other body capable of inductive action, with a closed circuit, so that the vibration of the one shall occasion electrical undulations in the other, or in itself," . . .

just what parts of the combination did you mean to indicate by the words "closed circuit" ?

Ans. I meant the conducting wire which formed the circuit or any portion of it.

Cross-Int. 774. Then I suppose the cores of the electro-magnets shown in Figs. 5, 6 and 7 were not elements of the combination which you intended to claim in Claim 2. Is that so?

Ans. They were elements that were shown and described in the body of the specification, but I did not consider it necessary to mention them specifically in the claim, because the coils would work without any cores at all within them; whereas, the cores would not be operative without the coils.

Cross-Int. 775. Did you ever use an apparatus similar to those described in Figs. 5 and 7, in which the coils were used without the cores, prior to the grant of your patent on the seventh day of March, 1876?

Ans. No; but I have subsequently to that date.

Cross-Int. 776. In the preparation of the specification and claims of your patent of March 7, 1876, with the object of defining as accurately as possible the invention which you had originated, what invention made by you did you intend to specify and define in the third claim?

Ans. I intended to specify a mode of inducing electrical undulations like sound vibrations, in a circuit containing a voltaic battery, by the sonorous vibration of the armature of an electro-magnet in front of one of its poles. This invention is more fully described and defined in the body of the specification, and is illustrated by Figs. 5, 6 and 7.

Cross-Int. 777. How did the invention which you intended to specify and define in Claim 3 differ from the invention which you intended to specify and define in Claim 1?

Ans. Claim 1 was a broad claim for the use of the undulatory current for the purposes specified, however produced. That is, for the use of an electrical current thrown into undulations analogous to sound vibrations, quite independently of the mode of producing these undulations.

Claim 3 is for a specific mode of inducing such undulations in a continuous voltaic current by the sonorous vibration of bodies capable of inductive action.

Cross-Int. 778. Having reference to Claim 3, does any figure or drawing of the patent illustrate the method of producing undulations in a continuous voltaic current by the vibration or motion of the conducting wire itself in the neighborhood of a body or bodies capable of inductive action?

Ans. Figs. 5, 6 and 7 illustrate the first part of Claim 3, in which undulations like sound vibrations are produced in a continuous voltaic current by the sonorous vibration of an armature in front of the pole of an electro-magnet. These diagrams — Figs. 5, 6 and 7 — would also illustrate the latter part of the claim, if the coil of the electro-magnet were attached to the vibratory part of the apparatus and the armature kept still, in the manner I have more fully described in my answers to Cross-interrogatories 769 and 771.

Cross-Int. 779. Was the method which you intended to claim in

the second part of Claim 3 ever put in operation by you prior to the issue of your patent on March 7, 1876?

Ans. No; but it was subsequently.

Cross-Int. 780. How does the apparatus used in carrying out the method which you intended to claim by Claim 3 differ from the apparatus which you intended to claim in Claim 2?

Ans. Claim 3 is limited to an apparatus of which a voltaic battery forms a part. Claim 2 is not so limited. I have referred to Claim 2 as covering a case in which no battery is employed; but I would like to modify my preceding answers so far as to say that I do not think I intended to limit Claim 2 to such a case. I think I intended Claim 2 to be broader than Claim 3, and include it. That is, that Claim 2 would cover cases in which a voltaic battery was or was not used; whereas, Claim 3 was limited to cases in which a voltaic battery was employed.

Cross-Int. 781. I understand you to say that Claim 3 was intended to be limited to a particular apparatus. Did you intend Claim 3 to cover a process or method, or did you intend it merely to cover an apparatus?

Ans. I did not intend Claim 3 to be limited to the apparatus shown in the patent. It was intended to cover a particular mode of producing electrical undulations like sound vibrations. It was intended to include more than the apparatus, and cover a process or method.

Cross-Int. 782. In the preparation of the specification and claims of your patent of March 7, 1876, with the object of defining as accurately as possible the invention which you had originated, what invention made by you did you intend to specify and define by Claim 4?

Ans. I intended to specify a method of producing electrical undulations like sound vibrations in a continuous voltaic circuit by causing a wire dipping slightly into mercury or other liquid forming part of the circuit, to be thrown into sonorous vibration by attaching it to the vibratory part of the apparatus illustrated in Fig. 5 or Fig. 7. The vertical vibration of the wire causes its end to dip more or less deeply in the liquid, and thus occasions variations in the resistance of the circuit that produce corresponding variations in the

intensity of the current traversing the circuit, analogous to sound vibrations. The invention is more fully set forth in the body of the specification and accompanying drawings. I intended Claim 4 to cover a mode of producing undulations like sound vibrations, by introducing into a voltaic circuit a variable resistance.

In the body of the specification, I say :

“Electrical undulations may also be caused by alternately increasing and diminishing the resistance of the circuit, or by alternately increasing and diminishing the power of the battery. The internal resistance of a battery is diminished by bringing the voltaic elements nearer together, and increased by placing them farther apart. The reciprocal vibration of the elements of a battery, therefore, occasions an undulatory action in the voltaic current. The external resistance may also be varied. For instance, let mercury or some other liquid form part of a voltaic circuit, then the more deeply the conducting-wire is immersed in the mercury or other liquid the less resistance does the liquid offer to the passage of the current. Hence, the vibration of the conducting-wire in mercury or other liquid included in the circuit occasions undulations in the current. The vertical vibration of the elements of a battery in the liquid in which they are immersed produces an undulatory action in the current by alternately increasing and diminishing the power of the battery.”

Cross-Int. 783. In view of your previous answers, will you please state why nothing is said in the 1st, 2d, 3d and 4th claims of your patent, of the transmission of sound or sound-signals?

Ans. It is not a fact that nothing is said about the transmission of sound or sound-signals, for the claims relate to that, and nothing else. It is the very subject-matter of the whole patent.

Cross Int. 784. It was not the object of my question to call on you for a construction of the claims of the patent as at present viewed by you; my question merely had reference to the phraseology of the claims, and I ask you now, why the word, “sound,” or “sound-signals” is not among the words found in the 1st, 2d, 3d and 4th claims.

Ans. They are there in substance. The whole patent refers to the transmission of sound and sound-signals. In the body of my specification I say: “In this specification the three words ‘oscillation,’ ‘vibration’ and ‘undulation’ are used synonymously.” The whole patent refers to the transmission of sound or sound-signals, and the words “oscillation,” “vibration” and “undulation” are

always used in the sense of sound vibrations or electrical undulations like sound vibrations. In the first claim, where I say "the receiver is set in vibration," I mean, of course, sonorous vibration, for all the vibrations referred to in the patent relate to sound. So, also, in the use of the word "undulatory" in the first claim, I allude to a current, the undulations of which are analogous to sound vibrations; and so with the other claims; the vibrations or undulations referred to in the 2d, 3d and 4th claims are sonorous vibrations or electrical undulations analogous to sonorous vibrations. As the whole subject-matter of the patent related to the transmission of sound or sound-signals, I did not consider it necessary to use the word "sound" every time the word "vibration" or "undulation" occurred, for all the vibrations and undulations referred to were sound vibrations or electrical undulations like sound vibrations. I intended to limit the signification of the words "oscillation," "vibration" and "undulation" to oscillations having the character of sound vibrations.

Cross-Int. 785. Did you intend the word "power" in the 4th claim of your patent to mean electro-motive force, or what did you intend it to mean?

Ans. I intended it to refer to an increase and diminution of the internal resistance of the battery. The whole of Claim 4 refers to a variable-resistance mode of producing electrical undulations. When the internal resistance of a battery is diminished, the intensity of the current produced by it becomes greater, and in that sense the power of the battery is increased, without any real increase of electro-motive force, the increase being due to the diminished resistance of the battery. I intended the word "power" in the 4th claim to refer to intensity or strength of current, and not to electro-motive force. As is well known, the intensity of a current equals the electro-motive force divided by the resistance, and any change of resistance, therefore, affects the intensity of the current.

Cross-Int. 786. I suppose you were aware, were you not, before any invention claimed in your patent of March 7, 1876, that intensity or strength of current could be varied gradually, either by varying the electro-motive force or varying the resistance?

Ans. Not so as to produce electrical undulations like sound vibrations; that was invented by me.

Cross-Int. 787. My question had no reference to electrical undulations or sound vibrations. With this explanation, please make a responsive answer to the question.

Ans. Before the date of any invention claimed by me in my patent of March 7, 1876, I was familiar with the well-known law that intensity equals electro-motive force divided by resistance; and I therefore knew, in a general way, that intensity or strength of current could be varied gradually either by varying the electro-motive force, or by varying the resistance, without having any conception of a periodic variation of intensity, like a sound vibration, accomplished in either of these ways. It was my knowledge, however, of the general law referred to above, that led me to invent the means claimed in my patent of March 7, 1876, of producing an undulatory current, in which a periodic change of intensity occurs with the frequency of a sound vibration, the different phases of intensity corresponding to different phases of density in the air while transmitting a sound. I refer to the magneto-electric mode of Claim 2 — of which Claim 3 is a sub-variety — and the variable-resistance mode of Claim 4. These modes were invented by me, and not known before.

Cross-Int. 788. In one of your answers this morning, you have referred to the following passage in the specification of your patent of March 7, 1876:

"In this specification the three words 'oscillation,' 'vibration,' and 'undulation,' are used synonymously, and in contradistinction to the terms 'intermittent' and 'pulsatory.'"

Did you intend when you drew that specification that the word "undulation" should have a different sense or meaning from that which had previously been given to it in the English language; or, in other words, did you intend to coin a word, or give to a word of the English language a meaning which had not before attached to it?

Ans. When I drew that specification, I had arrived at the conception of an entirely new species of electrical current, for which there was no name in the English language. I had, therefore, to coin a name for this kind of current, and I termed it an "undulatory" current, in contradistinction to the "intermittent" and "pulsatory" currents I had formerly employed in the production of sonorous effects by

electricity. The word "undulation" is used in a sense that is consistent with the meaning that had been previously given to it in the English language; but it is limited in its application so as to be synonymous with "oscillation" or "vibration." In its application to electricity, the word "undulation" is given a meaning that had not been previously given to it in the English language, because what I term an "electrical undulation" had no existence before the date of my invention; nor, so far as I know, had it even been conceived of. An electrical undulation, in the sense in which I employ the term, is an electrical change analogous to a sound vibration. Now, in a sonorous vibration, the air is subject to periodic, rapidly recurring changes of density. The density of the air, within each period of change, varies gradually by insensible gradations from a maximum to a minimum, and from the minimum back to the maximum, constituting a complete oscillation or vibration. The frequency with which these periodic changes recur — that is, the rate or number of vibrations per second of time — determines the *pitch*. The difference between the maximum and minimum density in each vibration constitutes amplitude of vibration, and determines the *loudness* of the sound perceived; and the mode by which the density of the air changes gradually by insensible degrees from the maximum to the minimum and back again constitutes the character or form of the sonorous vibration, and determines the *quality* of the sound heard by the ear.

An electrical undulation, in the sense in which I use the term in the patent, must correspond to an aerial sound vibration in the respects enumerated above; the various phases of density being represented upon the circuit by corresponding phases of intensity of current. In the specification I say:

"electrical undulations result from gradual changes of intensity exactly analogous to the changes in the density of air occasioned by simple pendulous vibrations. The electrical movement, like the aerial motion, can be represented by a sinusoidal curve or by the resultant of several sinusoidal curves."

The likeness between the electrical changes going on in the circuit, and the aerial changes going on at the same time in the air during the transmission of a sound, is the key-note to the whole patent.

There was no word to express the idea in the English language, and I have therefore, in my patent, used the term "undulatory" current, and electrical "undulation" in a technical and strictly limited sense, to express the conception.

Cross-Int. 789. Is there any language in the specification of the patent of March 7, 1876, which limits the meaning of the word "undulation" to the technical and strictly limited sense in which you say you used it?

Ans. Yes, the language I have just quoted from the patent in my last preceding answer.

Cross-Int. 790. You say in the patent :

"The electrical movement, like the aerial motion, can be represented by a sinusoidal curve or by the resultant of several sinusoidal curves."

The sinusoidal curves shown in the drawing of your patent, if used to represent aerial motion, would merely represent the amplitude and rapidity of the vibrations ; or, in other words, the pitch and loudness. Is that so?

Ans. No. Every sound has a certain quality or *timbre* of its own, as well as a certain pitch and loudness. Suppose that the sinusoidal curves, shown in Fig. 4 of the drawing of my patent, be used to represent an aerial sound vibration, then the horizontal distance d , between b and b , would represent the time taken to complete a single vibration, and would be the element representing pitch ; for the number of vibrations per second, or, in other words, the rate or frequency of vibration, determines pitch. The vertical distance between b and c , being the sum of the two lines $b d$ and $f c$, constitutes the amplitude of the vibration, and expresses the loudness of the sound ; and the shape or form of the curve between b and b represents the character or form of the sonorous vibration, and expresses the character, quality, or *timbre* of the sound represented.

Cross-Int. 791. Is there any statement in the specification of your patent to the effect that any sinusoidal curve illustrated therein expresses shape, or *timbre* or form of the sound?

Ans. The word "sinusoidal" itself indicates a curve of particular shape, and it was well known in the art that this shape of curve

represented graphically a simple pendulous vibration, or musical tone of simple quality.

In reference to the shapes of the sinusoidal curves in Fig. 4, as expressing electrical changes, I say :

“The vertical distance $b d$ or $c f$ of any portion of the curve from the zero-line expresses the intensity of the positive or negative impulse at the part observed.” . . .

In other words, in the electrical undulations represented by the curves in A, Fig. 4, the intensity of the current not only varies gradually from point to point, by insensible degrees, but varies in a particular manner, represented by the shape or form of the curves. This is specially evident in the curve $A+B$, in which the form of the resultant electrical undulation is different from that of either of its constituents, A and B. In reference to this, I say, in the body of the patent :

“The combined effect of A and B, when induced simultaneously on the same circuit, is expressed by the curve $A+B$, Fig. 4, which is the algebraical sum of the sinusoidal curves A and B. This curve $A+B$ also indicates the actual motion of the air when the two musical notes considered are sounded simultaneously. Thus, when electrical undulations of different rates are simultaneously induced in the same circuit, an effect is produced exactly analogous to that occasioned in the air by the vibration of the inducing bodies. Hence, the co-existence upon a telegraphic circuit of electrical vibrations of different pitch is manifested, not by the obliteration of the vibratory character of the current, but by peculiarities in the shapes of the electrical undulations, or, in other words, by peculiarities in the shapes of the curves which represent those undulations.”

In describing the operation of the apparatus shown in Fig 7, I say in the patent :

“When a sound is uttered in the cone the membrane a is set in vibration, the armature c is forced to partake of the motion, and thus electrical undulations are created upon the circuit $E b e f g$. These undulations are similar in form to the air vibrations caused by the sound — that is, they are represented graphically by similar curves.”

Cross-Int. 792. In the 3d claim of your patent of March 7, 1876, you use the following language :

“The method of producing undulations in a continuous voltaic current by the vibration or motion of bodies capable of inductive action ” . . .

A permanent magnet is a body capable of inductive action, is it not, within the meaning of the language used?

Ans. It is.

Cross-Int. 793. How, then, does the method which you intended to claim in Claim 3 differ from the mode of operation of the apparatus which you intended to claim in Claim 2?

Ans. I presume you intend to ask me how the method of producing electrical undulations described in Claim 3 differs from that described in Claim 2. The method described in Claim 3 is limited to a continuous voltaic current; whereas, that described in Claim 2 is not so limited, but is independent of the presence of a battery in the circuit.

Cross-Int. 794. If I understand your last answer correctly, the sole difference is, that in one case a battery is used, and in the other it is not used. Is that so?

Ans. I would rather say, in one case a battery is used, and in the other it need not be used. I look upon the method in Claim 3 as a sub-variety of the method described in Claim 2; it forms a particular case of the method set forth in Claim 2.

Cross-Int. 795. It is not positively necessary to use a battery in either case, is it, as you have said that bodies capable of inductive action, referred to in the 3d claim, include permanent magnets?

Ans. I did not intend that a case in which a voltaic battery was not used should come under Claim 3; but I believed it to be covered by Claim 2. A case in which a battery is used, I believed might come under both claims.

Cross-Int. 796. The word "battery" does not occur in any of the claims of the patent except the 4th, does it?

Ans. None of the claims excludes a battery, and in the 3d claim a battery is specifically indicated; for "a continuous voltaic current" necessitates a battery in the circuit.

Cross-Int. 797. You knew, did you not, before the invention of anything claimed in your patent of March 7, 1876, that variations of current-strength might be caused by alternately increasing and diminishing the resistance of the circuit, or by alternately increasing and diminishing the power of its battery?

Ans. Not such variations as constitute undulations, in the sense

of the patent; that is, electrical undulations analogous to sound vibrations.

Cross-Int. 798. I gather from your last answer, that, with the exceptions stated therein, you did know, prior to the making of any invention claimed in your patent of March 7, 1876, that variations of current-strength could be caused by alternately increasing and diminishing the resistance of the circuit, or by alternately increasing and diminishing the power of the battery. Is that so?

Ans. Certainly I knew that if you diminished the resistance of a circuit without changing the electro-motive force, the intensity of the current would be increased; and conversely, if you increased the resistance, the intensity would be diminished. And so with the power of the battery. I knew that if you changed the internal resistance of the battery, you would cause a change in the intensity of the current; but the very idea of a rapid, periodic change of intensity in an electrical current, corresponding exactly to a sound vibration, was unknown before my invention of it; nor was any method known to me, or to others, of varying the resistance of a circuit or the power of a battery so as to produce undulations of this character, until my invention of the method set forth in my patent of March 7, 1876, and claimed in Claim 4.

Cross-Int. 799. I gather from your answer to Question 788, that in order to create an electrical undulation in the sense in which you use the term in your patent, by means of the apparatus illustrated in Fig. 5 of the drawings of the patent, it would be necessary to cause the armature *c* to vibrate with sufficient rapidity to create a sonorous vibration in the air. Is that so?

Ans. Yes.

Cross-Int. 800. And in order to create an electrical undulation in the sense in which you use the words in the patent, by means of Fig. 7 of the patent, it would be necessary to cause the armature *c* to vibrate with sufficient rapidity to cause sonorous vibrations in the air. Is that so?

Ans. Not only so, but the motion of the armature is itself caused by the agency of a sonorous vibration in the air. Through the interposition of the membrane the vibrating air is enabled to control the motion of the armature *c*, so that the vibration of the armature

c is a *facsimile* copy of the aerial sound vibration that causes its motion. In the case of both Fig. 5 and Fig. 7, the armature must oscillate with the frequency of a sonorous vibration in order to create an electrical "undulation" in the sense I used the word in the patent, but the means whereby the armatures are thrown into sonorous vibration are radically different in the two cases — Fig. 5 and Fig. 7. In the case of Fig. 5, the armature *c* is set mechanically into vibration in any convenient way (for example, by wind) and its vibration causes, on the one hand, sonorous vibrations in the air, and on the other hand, electrical undulations in the circuit *g b e f g*, which are analogous to the aerial vibrations. In this case, the sonorous vibration is the result of the vibration of the armature *c*.

In the case of Fig. 7, the vibration of the armature *c* is the result of the sonorous vibration, and not its cause. Motion is imparted to the armature by the human voice or by means of a musical instrument, or by sounds produced in any way in the neighborhood of the membrane *a*. In the operation of the apparatus, Fig. 7, as described in the patent, a sound is uttered into the cone *A*; the sonorous vibration caused by the voice occasions a like vibration of the membrane *a*; the armature *c* being attached to the centre of the membrane is forced to partake of the motion, and to move in like manner, thus creating electrical undulations of similar character in the circuit *E b e f g*. Thus, in Fig. 7, sonorous vibrations existing in the air cause vibrations of the armature *c*, and these, in turn, occasion electrical undulations which resemble the sonorous vibrations of the air. In the case of Fig. 5, the mechanical vibration of the armature *c* causes sonorous vibrations to appear in the air, and at the same time causes electrical undulations resembling the sonorous vibrations produced in the air. In the case of Fig. 5, the sonorous vibrations existing in the air are the result of the vibration of the armature *c*; in the case of Fig. 7, they are the cause.

Cross-Int. 801. I understand from your answers that the armature *c* of Fig. 5 must oscillate with the frequency of a sonorous vibration in order to create an electrical undulation. I suppose that the converse of this proposition is true, and that if the armature *c* does not oscillate with the frequency of a sonorous vibration, then

an electrical "undulation," in the sense that you intended to use the word in the specification, will not be created. Is that so?

Ans. That is so.

Cross-Int. 802. Please answer the same question with reference to the armature *c* of Fig. 7.

Ans. In regard to Fig. 7 also; in order to create on the circuit electrical "undulations" in the sense that I used that word in my patent of March 7, 1876, the armature *c* must oscillate with the frequency of a sonorous vibration.

Cross-Int. 803. And, having reference to the apparatus shown in Fig. 5, is it necessary, also, that the armature of the receiving instrument should oscillate with the frequency of a sonorous vibration in all cases in which electrical undulations are created?

Ans. In the case of Fig. 5 it is necessary that the armature of the receiving instrument should oscillate with the frequency of a sonorous vibration when the frequency of the electrical undulations corresponds to the normal rate of vibration of the armature of the receiving instrument; that is, when the armatures of the transmitting and receiving instruments have normally the same pitch. When the pitches are different, it is neither necessary nor advisable that the armature of the receiving instrument should oscillate at all. For the purpose of the invention illustrated by Fig. 5, it would be an actual disadvantage to have the armature of the receiving instrument thrown into forcible vibration so as to produce a sensible sound in cases where the armatures of the transmitting and receiving instruments were not in unison.

[*Because of an error in numbering, there was no Cross-Int. 804.*]

Cross-Int. 805. Again having reference to Fig. 5: When the armature *c* of the transmitting instrument oscillates with the frequency of a sonorous vibration, and the armature of the receiving instrument has a different rate of vibration, and remains silent, is an electrical undulation created, in the sense in which you use the words in the specification?

Ans. In all cases where the armature *c* of the transmitting instrument oscillates with the frequency of a sonorous vibration, electrical undulations are created, in the sense in which I used the word in the specification, whether the receiving instrument responds or not.

Cross-Int. 806. Then if I understand your answers correctly, if a permanent magnet is placed in the coil of a closed circuit and a tuning-fork is made to vibrate in the presence of the permanent magnet, an electrical undulation, in the sense in which you use the words in the specification, would be created. That is so, is it?

Ans. If I understand you correctly, you propose to substitute for the core of the electro-magnet A, shown in Fig 5, a permanent magnet, and for the armature c, a tuning-fork; and ask whether the sonorous vibration of the tuning-fork in front of the pole of the permanent magnet would create, in the circuit *g b e f g*, electrical undulations, in the sense in which I intended to use the term in the patent. It would; whether a battery was present in the circuit or not.

Cross-Int. 807. I asked you yesterday whether there was any statement in the specification of your patent to the effect that any sinusoidal curve illustrated therein expressed shape, or *timbre*, or form of the sound; and in your reply you quoted certain passages from the specification. Is there any other statement in the specification besides those quoted by you, to the effect that any sinusoidal curve illustrated therein expresses the *timbre* or quality of sound?

Ans. The patent assumes a knowledge of the state of the art in relation to acoustics, and the matter inquired about was well-known in the art at the time.

Cross-Int. 808. It was known to you, was it not, from others or from printed publications, prior to any invention claimed in your patent of March 7, 1876, that the internal resistance of a battery is diminished by bringing the voltaic elements of a battery nearer together, and increased by placing them farther apart?

Ans. Yes; but it was not known that the reciprocal sonorous vibration of the elements of a battery in this way would occasion "undulations" in a continuous voltaic circuit, in the sense in which I used that word in the patent.

Cross-Int. 809. Is any apparatus described or illustrated in the patent of March 7, 1876, for bringing voltaic elements nearer together, or placing them farther apart?

Ans. This can be accomplished by attaching the element of the battery which we desire to throw into sonorous vibration, to the

vibratory part of the apparatus shown in Fig. 5 or Fig. 7. That is, in the case of Fig. 5, the element of the battery is to be thrown into vibration through the agency of a tuned reed blown by wind, or set in vibration by mechanical means. In the case of Fig. 7, sonorous vibrations can be imparted to the element of the battery through the agency of a stretched membrane.

Cross-Int. 810. Was any such apparatus as that imagined by you in your last answer made or used by you prior to March 7, 1876; or was any drawing of such an apparatus made by you prior to March 7, 1876?

Ans. No; but such an apparatus was constructed and used by me subsequently to that date; and I think also that drawings were made at the same time.

Cross-Int. 811. Did you know from printed publications or from others, prior to any invention claimed in your patent of March 7, 1876, that the reciprocal vibration of the elements of a battery occasioned variations in the strength of the voltaic current? This question, you will note, has no reference to any meaning which you have attached to the word "undulatory" or "undulatory action."

Ans. What I knew and did not know prior to any invention claimed by me in my patent of March 7, 1876, in relation to this matter, will be best understood by quoting a passage from the specification. In my patent I say:

"The internal resistance of a battery is diminished by bringing the voltaic elements nearer together, and increased by placing them farther apart. The reciprocal vibration of the elements of a battery, therefore, occasions an undulatory action in the voltaic current."

The first sentence expresses the condition of my knowledge on the subject, prior to any invention claimed by me in my patent. The last sentence was an inference of my own, drawn from the premises stated in the first sentence.

In my patent, of course, the word "vibration" in the second sentence is used in the sense of sonorous vibration, and "undulatory" in the technical sense that I have given it in my patent. You ask me, however, to answer the question without reference to the technical meaning given to these words in the patent. I may say, then, that so far as I know, it was not known prior to any invention

claimed by me in my patent of March 7, 1876, that the reciprocal vibration of the elements of a battery would occasion variations in the strength of a voltaic current, of such a character that the same curve which should graphically represent the mechanical vibration would also represent in a graphical manner the variations in the strength of the voltaic current. There was nothing in the state of the art to prevent anyone from arriving at this conclusion; but as a matter of fact, so far as I know, no one did reach the conception until I myself arrived at it. And this I believe to be true of vibrations too slow to produce the sensation of sound; although in my patent I limit myself to sonorous vibrations and electrical undulations that correspond to sonorous vibrations.

Cross-Int. 812. Is any apparatus described and illustrated in your patent of March 7, 1876, in which "the reciprocal vibration of the elements of a battery occasions an undulatory action in the voltaic current"? In this question, you will note I quote the precise language of the specification.

Ans. No; but I believed that anyone skilled in the arts to which the patent refers would understand that a membrane like that shown at *a*, Fig. 7, when actuated by the voice of a speaker, would cause vibration in any attached mass similar to the armature *c*, whatever the form of that mass might be; so that in any case where I speak in the patent of causing vibrations in a body, without specifically describing the means whereby the vibration is to be accomplished, I believed that it would be understood that the means shown in Fig. 5 or Fig. 7 could be adapted to the purpose by attaching the body it was desired to vibrate to the vibratory part of the apparatus shown in Fig. 5 or Fig. 7. That is, by attaching it in the one case to a tuned reed blown by wind, or otherwise operated by mechanical means, illustrated in Fig. 5; or, in the other case, by attaching it to a stretched membrane which could be thrown into vibration by the voice of a speaker, as in Fig. 7. I did not think that it required invention to arrive at this conception, but thought that anyone skilled in the arts to which the patent refers would understand this without further instruction than is contained in the patent itself.

Cross-Int. 813. Was any apparatus similar to that which you have imagined in your last answer constructed or used by you prior to

March 7, 1876; or was any drawing of such an apparatus made prior to March 7, 1876?

Ans. I understand you to refer to the vibratory part of the apparatus shown in Figs. 5 and 7, as distinct from the electrical part. I may say, then, that prior to March 7, 1876, I had been in the habit of experimenting with membranes like that shown at *a* in Fig 7, which were loaded in different ways. I allude specially to experiments with phonautographs, in which the load carried by the membrane not only greatly exceeded the weight of the armature *c*, but also did considerable mechanical work in scraping lampblack from a smoked-glass plate in forming graphical tracings of the forms of vibration characterizing speech sounds. I had also been in the habit of using free reeds like that shown in Fig. 5, which were loaded in various ways; for example, by the attachment of a wire. Before March 7, 1876, then, I had constructed and used substantially the vibratory parts of the apparatus shown in Figs. 5 and 7, and was perfectly familiar with the fact that they could be loaded in various ways, without materially affecting their vibration. Drawings of the apparatus referred to were also made before March 7, 1876.

Cross-Int. 814. Did you know from printed publications, or from others, prior to any invention made by you in your patent of March 7, 1876, that the vertical vibration of the elements of a battery in the liquid in which they are immersed produces a variation in the strength of the current by alternately increasing and diminishing the power of the battery?

Ans. No; what I did know was, that if the elements of a battery dipped very slightly into the exciting liquid, the strength of the current produced would be less than if a larger area of surface were brought in contact with the liquid by causing the elements to dip more deeply into the liquid. From this premise I inferred not only that the vertical vibration of the elements of a battery in the liquid in which they are immersed would produce a variation in the strength of the current, but that these variations would be proportional to the amount of surface immersed, so that electrical undulations, in the sense I used that term in the patent, would be produced, if the vibrations succeeded one another with the frequency of a sound vibration. There was nothing in the state of the art to pre-

vent anyone from arriving at this conception before I did ; but the fact is, so far as I know, that no one did reach the conception until after I myself had arrived at it. And I say this, not only in regard to sonorous vibrations like those alluded to in the patent, but also in regard to vibrations too slow to produce the sensation of sound ; although in my patent I limit myself to sonorous vibrations, and to electrical undulations corresponding to sonorous vibrations.

Cross-Int. 815. Is any apparatus described in the specification of your patent of March 7, 1876, or shown in the drawings thereof, for causing the vertical vibration of the elements of a battery in the liquid in which they are immersed?

Ans. The vibratory part of the apparatus shown in Fig. 5 or Fig. 7. I allude to a free reed, blown by wind, in the case of Fig. 5 ; and a membrane, actuated by the human voice, in the case of Fig. 7. I thought that anyone skilled in the art would understand that these were the means I proposed for producing the vibrations alluded to in the patent.

Cross-Int. 816. Voltaic batteries are illustrated in the conventional manner in the drawings of your patent of March 7, 1876, in Figs. 5, 6 and 7 ; that is to say, by vertical lines in Figs. 5 and 6, and horizontal lines in Fig. 7 ; are they not?

Ans. Yes.

Cross-Int. 817. No other graphical illustrations or drawings of a battery are to be found in the patent, except those referred to in my last question. That is so, is it not?

Ans. Yes ; that is so.

Cross-Int. 818. I notice in Fig. 5 the battery is represented as being placed in a circuit composed wholly of the wires, and in Fig. 7 it is represented as being placed in a circuit composed partly of the wires and partly of the ground. Does any significance or important attach to that?

Ans. No. The one form of circuit is a well-known equivalent for the other. It is immaterial to the operation of the apparatus which form is employed.

Cross-Int. 819. Did you, before the issue of your patent of March 7, 1876, make or use an apparatus in which the elements of

a battery were vertically vibrated ; or did you before March 7, 1876, make a drawing of such an apparatus?

Ans. No.

Cross-Int. 820. Did you know from others, or from a printed publication or publications, prior to the date of any invention claimed in your patent of March 7, 1876, that when mercury or some other liquid forms part of a voltaic circuit, the more deeply the conducting wire is immersed in the liquid, the less resistance does the liquid offer to the passage of the current?

Ans. I would rather say that I knew, prior to the date of any invention claimed in my patent of March 7, 1876, that when a liquid formed part of a voltaic circuit, the resistance of the liquid path depended very greatly upon the amount of surface of the conductors immersed in the liquid. But I cannot say that I learned this from others or from printed publications, although the fact was known. I think I learned this from my own experiments with a spark-arrester, in which liquid was employed. I allude to the spark-arrester described in my answer to Interrogatory 103.

Cross-Int. 821. When, if ever, did you receive information that the spark-arrester referred to in your last answer was not patentable because of lack of novelty therein?

Ans. I do not think I ever received information that it was not patentable because of lack of novelty therein ; for I did not get the impression that there were no patentable features about it at all. My specification was forwarded to Messrs. Pollok & Bailey at Washington, I think, in January, 1876, or perhaps February, and so far as I remember, they informed me that I had been anticipated in some important point, so that the specification would have to be amended if I desired to apply for a patent. My recollection is that as the use of the undulatory current for the purposes of multiple telegraphy rendered the spark-arrester unnecessary, I did not think it worth while pursuing the matter.

Cross-Int. 822. Do you remember whether the vibration of the conducting wire in mercury or other liquid was one of the important points which was held by your attorneys to have been anticipated?

Ans. That was not one of the points. I presume you use the word "vibration" in its ordinary sense, as used in physics, and

defined in the dictionary ; and not merely in the restricted sense in which I employ the term in my patent, viz., sonorous vibration. I think the point was, that a liquid like water had before been employed as a spark-arrester.

Cross-Int. 823. Is any apparatus illustrated in the drawings of your patent in which the vibration of a conducting wire in mercury or other liquid included in the circuit, is shown, or is there any description of such an apparatus in the specification?

Ans. I think that a careful reading of the specification would enable anyone skilled in the art to construct such an apparatus. I did not intend to speak of the sonorous vibration of any body, without showing a means whereby that sonorous vibration could be effected ; and I believed that anyone skilled in the art would understand that the means of effecting this, shown in Fig. 5 or Fig. 7, were applicable to all the cases mentioned in the patent. For example, in the case of Fig. 5, I thought that anyone would understand that the conducting wire to be vibrated might be attached to a free reed, *c*, blown by wind, or set mechanically in vibration ; and that mercury or other liquid should be substituted for the electro-magnet *b*. So again in the case of Fig. 7, I presumed it would be understood that the conducting wire to be vibrated might be attached to the centre of a stretched membrane, *a* ; and that the mercury or other liquid should be included in the circuit in place of the electro-magnet *b*.

Of course, in this case, as the surface of the mercury or other liquid would necessarily be horizontal, the membrane *a* would require to be substantially horizontal in order to allow the wire to dip into the liquid. I presumed that this would be understood by anyone skilled in the art, without any further description than is contained in the patent itself.

Cross-Int. 824. Was either form of apparatus imagined by you in your last answer constructed or used by you prior to the seventh day of March, 1876?

Ans. No ; but both were constructed very shortly afterwards.

Cross-Int. 825. When you prepared the specification of your patent of March 7, 1876, did you intend that the apparatus shown in Fig. 5 of the drawings should be used for the purpose of transmitting articulate speech?

Ans. No; not as shown in Fig. 5 of the drawings.

Cross-Int. 826. What features of construction are absent in the apparatus shown in Fig. 5, and present in the apparatus shown in Fig. 7, which would enable an operator to transmit speech with the latter instrument?

Ans. An armature having no tendency to vibrate at a definite rate of its own, and a stretched membrane; combined together as shown in Fig. 7. In the body of the specification these features are described as follows:

“One of the ways in which the armature *c*, Fig. 5, may be set in vibration has been stated above to be by wind. Another mode is shown in Fig. 7, whereby motion can be imparted to the armature by the human voice or by means of a musical instrument.

“The armature *c*, Fig. 7, is fastened loosely by one extremity to the uncovered leg *d* of the electro-magnet *b*, and its other extremity is attached to the centre of a stretched membrane, *a*.”

Cross-Int. 827. Then, if I understand your answer correctly, the advance in the art over what is shown in Fig. 5, or the improvement on what is shown in Fig. 5, which accomplished the transmission of articulate speech, was the substitution of an armature having no tendency to vibrate at a definite rate of its own, and the provision of a stretched membrane, the parts being combined as illustrated in Fig. 7 of the patent. That is so, is it not?

Ans. No; that was an improvement in the apparatus shown in Fig. 5, so as to enable it to accomplish the transmission of articulate speech and other sounds, by arranging it as in Fig. 7; but that had nothing to do with the art, which was quite independent of any armature or any membrane. The art or method of transmitting vocal or other sounds telegraphically as defined and claimed in the patent, consists in “causing electrical undulations similar in form to the vibrations of the air accompanying the said vocal or other sounds.” Fig. 7 is simply one form of apparatus for accomplishing this result.

Cross-Int. 828. In the specification of your patent you say: “One of the ways in which the armature *c*, Fig. 5, may be set in vibration has been stated above to be by wind.” Did you, when you prepared the specification, mean by the word “wind,” any motion of

the surrounding air which would set the armature *c* in vibration ; or what did you mean by it?

Ans. I meant that the armature *c*, Fig. 5, could be arranged in a metallic bed in the ordinary way, so as to constitute a free reed like that employed in organs, which could be set in sonorous vibration by a current of air from a wind-chest or bellows.

I may say that I constructed an apparatus arranged in this manner before the specification of my patent of March 7, 1876, was written, and operated it successfully.

Cross-Int. 829. When was it that the apparatus mentioned in your last answer was constructed?

Ans. On the 28th of June, 1875. In a letter which I wrote to Mr. Hubbard on that day, and which I read in my answer to Interrogatory 73, I described the apparatus and the experiments made with it at that time.

Cross-Int. 830. Then, if I understand your testimony correctly, as early as the 28th of June, 1875, you had constructed and used the apparatus shown in Fig. 5; and subsequent to that date an apparatus similar to that shown in Fig. 7 was constructed, having the improvements by means of which articulate speech could be transmitted. That is so, is it not?

Ans. On the 28th of June, 1875, I successfully used an apparatus like that shown in Fig. 5, in which the armature *c* was arranged as a free reed, and blown by wind. This constituted a reduction to practice of the invention illustrated by Fig. 5, but it was not the first reduction to practice. On the 2d of June, 1875, I also successfully operated apparatus like that shown in Fig. 5, causing the sonorous vibration of the armature *c* by plucking it, and thus setting it mechanically in vibration. I gave orders for the construction of the apparatus shown in Fig. 7 on the second day of June, 1875. One of the telephone instruments shown in Fig. 7 was constructed in the month of June, 1875—I believe before the twenty-eighth day of that month—and the other was completed very shortly after the first of July.

Cross-Int. 831. When was the first reduction to practice of the apparatus shown in Fig. 5?

Ans. On the second day of June, 1875.

Cross-Int. 832. I believe that you have stated that you prepared the 3d claim of your patent No. 186,787, dated January 30, 1877.

In view of your testimony concerning Fig. 5 of your patent No. 174,465, and the description thereof in the specification, will you please state why the 3d claim referred to was placed in the specification of the patent No. 186,787, instead of in the specification of the patent No. 174,465.

Ans. Yes; I prepared the 3d claim of my patent No. 186,787, dated January 30, 1877; but it would not have been possible for me to have placed that claim in my patent No. 174,465, of March 7, 1876, because the combination referred to in the claim had not then been invented; and even if it had been invented, it would not have been proper for me to have included it in that patent, because I had not shown in that patent a plate of iron or steel capable of being thrown into vibration by sounds made in its neighborhood, so that it could be substituted for the combined membrane and armature shown in Fig. 7 of that patent.

Cross-Int. 833. Did you not, when you prepared the specification of patent No. 174,465, consider wind to be a movement of the surrounding air?

Ans. Not in the sense in which those words are used in the 3d claim of patent No. 186,787. In that claim I intended the expression to refer to a sonorous vibration of the surrounding air. The meaning of the language employed will be more clearly understood by reference to the body of the specification, wherein I point out the difference between the invention described and claimed therein, and the invention disclosed in my patent of March 7, 1876. In my patent No. 186,787, I say:

"In my Patent No. 174, 465, dated March 7, 1876, I have shown as one form of transmitting-instrument a stretched membrane to which the armature of an electro-magnet is attached, whereby motion can be imparted to the armature by the human voice, or by means of a musical instrument, or by sounds produced in any way.

"In accordance with my present invention I substitute for the membrane and armature shown in the transmitting and receiving instruments alluded to above, a plate of iron or steel capable of being thrown into vibration by sounds made in its neighborhood."

Cross-Int. 834. A loud noise made in the vicinity of the plate c,

shown in Fig. 5 of your patent No. 174,465, will create a movement of the surrounding air which will set the plate *c* in vibration ; will it not?

Ans. The spring of the reed would prevent the armature *c* from copying the aerial vibration. The reed has a tendency to vibrate at a definite rate of its own, and it cannot be substituted in a speaking telephone for the combined membrane and armature shown in Fig. 7. It is a different sort of plate altogether from that referred to in the 3d claim of my patent No. 186,787.

Cross-Int. 835. I did not intend by my last question to question you as to the extent to which the reed *c* would copy aerial vibrations ; but I merely inquired whether a loud sound made in the vicinity of the plate *c*, Fig. 5 of your patent No. 174, 465, would not create a movement of the surrounding air which would throw the plate *c* into vibration.

Ans. It would depend a great deal upon the pitch of the sound. If the loud sound had the same pitch as that normally produced by the reed when freely vibrating after being plucked, then it would throw the reed into vibration ; but if the loud sound had a different pitch, then the sonorous vibration of the air would interfere with the vibration of the reed *c*. Suppose, for example, that the reed should be in full vibration at the time the loud sound of different pitch is made, then the loud sonorous vibration existing in the air will tend to check the vibration of the reed and bring it to rest.

Cross-Int. 836. I do not think that you have yet fully answered my last question ; and I will ask you again, whether or not any loud sound made in the vicinity of the plate *c*, Fig. 5, would create a movement of the surrounding air which would throw the said plate into vibration, whether the pitch of the said sound was the same as the reed *c* or different therefrom.

Ans. It seems to me that I have fully answered the question ; but in order that there may be no misunderstanding, I may say again, that a sound made in the vicinity of the free tuned-reed *c*, Fig. 5, if of different pitch from the tone normally produced by the reed, would create a movement of the surrounding air which, so far from having a tendency to throw the reed into vibration, actually has a tendency to check and stop its vibration ; so that if the reed vibrates

at all, it vibrates by virtue of other causes than the presence of the sonorous vibration of the air, for that has a tendency to check its motion.

Cross-Int. 837. If a loud sound of the same pitch as that of the plate armature *c*, Fig. 5 of your patent No. 174,465, is made in the vicinity of the armature *c*, will that sound be transmitted and heard at the receiver of the instrument?

Ans. A sound will be heard at the receiving instrument having the same pitch as the loud sound considered, but not necessarily having the same quality or *timbre*. The question, of course, assumes that the instruments are arranged as in Fig. 5 of my patent No. 174,465, with the armatures, *c*, *h*, of the two instruments, A, I, normally in unison with one another.

Cross-Int. 838. Claim 3 of your patent No. 186,787, referred to, is in the following language:

"3. The combination, with an electro-magnet, of a plate of iron or steel, or other material capable of inductive action, which can be thrown into vibration by the movement of surrounding air or by the attraction of a magnet."

It is true, is it not, that the receiving instrument, Fig. 5, of your patent No. 174,465, has a plate of iron or steel or other material capable of inductive action which can be thrown into vibration by the attraction of a magnet?

Ans. Yes; but it does not have such a plate as is referred to in Claim 3 of my patent No. 186,787, which is defined in the body of the specification as a plate of iron or steel capable of being thrown into vibration by sounds made in its neighborhood, so that it forms at the same time both a diaphragm and an armature capable of being substituted for the combined membrane and armature shown in Fig. 7 of my patent of March 7, 1876. Nor does the combination of electro-magnet and armature, shown in Fig. 5 of my patent No. 174,465, constitute an electric speaking telephone like the combination in Claim 3 of my patent of January 30, 1877, No. 186,787.

Cross-Int. 839. You say, in answer to Cross-question 827, that the art or method of transmitting vocal or other sounds telegraphically, as defined and claimed in the patent, consists in causing electrical undulations similar in form to the vibrations of the air

accompanying said vocal or other sounds; and that Fig. 7 is simply one form of apparatus for accomplishing this result. Do you mean by this answer that there are other forms of apparatus for accomplishing this result referred to in the specification of your patent of March 7, 1876?

Ans. I meant that when I claimed the art or method referred to, as I did in Claim 5 of my patent of March 7, 1876, I believed it was necessary for me to show one form of apparatus for accomplishing the result, which I did in Fig. 7. I also meant that I did not intend to limit myself to the particular apparatus shown in Fig. 7, but believed that the art might be practised by other forms of apparatus; but that it was only necessary for me to show one in order to claim the method or art. I understood by your question that you meant to ask me whether there are other forms of apparatus for accomplishing the result referred to in my patent; if, however, by the question, you meant to ask me whether there are other forms of apparatus referred to in my patent for accomplishing the result, then I would answer that there are. They are referred to, but are not specifically described in full and illustrated by drawings, but I think they are sufficiently suggested to enable anyone skilled in the art to make them.

Cross-Int. 840. Please state those parts of the specification which refer to other forms of apparatus, besides Fig. 7, for accomplishing the result mentioned in your answer to Question 827; that is to say, "causing electrical undulations similar in form to the vibrations of the air accompanying the said vocal or other sounds."

Ans. In Claims 2, 3 and 4 of my patent of March 7, 1876, I have specified and claimed certain methods of producing electrical "undulations" suitable for the purposes of my invention, either for use in multiple telegraphy — as in the case of the method illustrated in Fig. 5 — or for the purpose of transmitting vocal or other sounds telegraphically — as in the case of the method illustrated in Fig. 7. The instrumentalities alluded to in the claims, and more fully described in the body of the specification, when combined in the manner claimed, constitute apparatus for carrying the methods into effect. One such combination or apparatus for practising the art or method covered by Claim 5, and referred to in your question, is fully

and clearly set forth in the specification, and illustrated in Fig. 7; and the combinations of instrumentalities referred to in Claims 2, 3 and 4, so far as they can be employed in practising that art, and are different from the combination shown in Fig. 7, suggest modifications of the apparatus shown in Fig. 7. For example, the specific apparatus of Fig. 7, so far as it illustrates the method of Claim 2, shows a body capable of inductive action, viz, the armature *c*, Fig. 7, set in sonorous vibration by a stretched membrane *a*, in the neighborhood of the conducting-wire forming the circuit, viz, the coil *b* of the electro-magnet.

The apparatus of Fig. 7, then, specifically illustrates the first part of Claim 2. The second part of Claim 2 suggests that the result could be equally well obtained by vibrating the coil by the membrane in the neighborhood of the armature, as by vibrating the armature in the neighborhood of the coil. It also suggests that both coil and armature might be attached to distinct membranes so as both to be set simultaneously into sonorous vibration in each other's neighborhood by the action of the voice. As I picture this suggested apparatus in my mind, it would consist of a telephone in the form of a drum, with the electro-magnet and armature inside; one drum-head carrying the electro-magnet or coil, and the other the armature *c*; the voice of the speaker being directed into the interior of the drum so as to cause the drum-heads to move in opposite phases, and thus accomplish the vibration of the armature and coil in each other's neighborhood. Of course, in all the cases alluded to above, a skilled person would proportion the parts properly to one another, so that they would vibrate in the manner desired; that is, he would use membranes stout enough to move the attached parts, and coils or armatures light enough to be carried by the membranes. Claim 2 also, by the omission to specify any battery, suggests that the apparatus of Fig. 7 might be employed without a battery. It also suggests a form of apparatus like Fig. 7, in which the armature *c* should consist of a permanent magnet.

In the case of Claim 3, the apparatus of Fig. 7 illustrates specifically the first part of the claim; the armature *c* being the body capable of inductive action, vibrated by the membrane *a*, so as to produce undulations in the continuous voltaic current produced by

the battery in the circuit $E b e f g$. The second part of the claim suggests that the same result would be effected if we could cause the conducting wire of the coil b to be vibrated by the membrane in the neighborhood of the armature c .

Claim 4 is for a variable-resistance method of producing undulations, as an equivalent of the magneto-electric method illustrated by Fig. 7. It suggests, therefore, the substitution of the variable-resistance instrumentalities specified in the patent, for the magneto-electric instrumentalities shown in Fig. 7. That is, the substitution of the variable-resistance instrumentalities in place of the electro-magnet b and armature c of Fig. 7. In reference to the instrumentalities that may be employed in producing electrical undulations by variation of resistance, I say, in the body of the specification :

“Electrical undulations may also be caused by alternately increasing and diminishing the resistance of the circuit, or by alternately increasing and diminishing the power of the battery.”

I then go on to specify three means for accomplishing this result :

1. “The internal resistance of a battery is diminished by bringing the voltaic elements nearer together, and increased by placing them farther apart. The reciprocal vibration of the elements of a battery, therefore, occasions an undulatory action in the voltaic current.”

2. “The external resistance may also be varied. For instance, let mercury or some other liquid form part of a voltaic circuit, then the more deeply the conducting-wire is immersed in the mercury or other liquid the less resistance does the liquid offer to the passage of the current. Hence, the vibration of the conducting-wire in mercury or other liquid included in the circuit occasions undulations in the current.

3. “The vertical vibration of the elements of a battery in the liquid in which they are immersed produces an undulatory action in the current by alternately increasing and diminishing the power of the battery.”

The first plan suggests the substitution of the elements of a battery for the electro-magnet b and the armature c of Fig. 7, and the attachment of one of the elements to the membrane a , so that it may be thrown into vibration by the voice of a speaker in such a manner that the distance between the elements of the battery shall be alternately increased and diminished so as to produce electrical undula-

tions upon the circuit, similar in form to the vibration of the air accompanying the sound uttered. It also suggests a drum-like form of apparatus with two membranes, each carrying one element, so as to occasion the reciprocal vibration of the elements of the battery.

The second plan suggests the substitution for the electro-magnet *b* and armature *c* of Fig. 7, of a vessel containing mercury or some other liquid forming part of the voltaic circuit, and the attachment of a conducting wire, forming part of the same circuit, to the membrane *a*, in such a manner that the end of the conducting wire shall be immersed to a greater or less extent in the mercury or other liquid, in accordance with the vibration of the membrane *a*. This suggests that the membrane should be horizontal and the wire vertical. The second plan also suggests that the wire should be so arranged relatively to the mercury or other liquid that its sonorous vibration in a vertical direction by the membrane shall cause a substantial variation in the resistance of the liquid path, and thus produce electrical undulations of sufficient magnitude to be used for the purpose of transmitting vocal or other sounds telegraphically. The resistance offered by the liquid to the passage of the current depends very greatly upon the depth of immersion of the conducting wire; the greater the amount of surface of the wire in contact with the liquid, the less the resistance. In making the apparatus, therefore, suggested by the second plan, a skilled person would so arrange the parts that the slight vertical displacement of the wire caused by the sonorous vibration of the membrane should cause as great a change as possible in the amount of surface in contact with the liquid; so that the sonorous vibration of the wire in a vertical direction should occasion as great a variation as possible in the resistance of the circuit. A skilled person would therefore arrange the wire relatively to the liquid so that its end should be immersed as slightly as possible consistently with the condition that it must not break contact with the surface of the mercury or other liquid during the vibration of the membrane.

The third plan suggests the substitution for the electro-magnet *b* and armature *c* of Fig. 7 of the elements of a battery and the attachment of both elements to the membrane *a*, so that the sonorous vibration of the membrane shall cause them to be vibrated in a ver-

tical direction in the liquid in which they are immersed. The passage suggests that the membrane α should be horizontal; that the elements of the battery should be attached to the under side of the membrane; and that the lower ends of the elements should be immersed in the battery fluid as slightly as possible, consistently with the condition that they shall not break contact with the liquid during the vibration of the membrane.

In reply to your question, I have specified certain modifications of the apparatus shown in Fig. 7 which are suggested in my patent No. 174,465 as equivalents for the specific apparatus illustrated in Fig. 7. I do not understand that your question calls for any description of the equivalents of the apparatus shown in Fig. 5.

Cross-Int. 841. You say, in answer to Question 837:

"A sound will be heard at the receiving instrument, having the same pitch as the loud sound considered, but not necessarily having the same quality or *timbre*. The question, of course, assumes that the instruments are arranged as in Fig. 5 of my patent No. 174,465, with the armatures c , h , of the two instruments, A, I, normally in unison with one another."

If a loud sound of the same pitch as that of the plate armature c , Fig. 5 of your patent No. 174,465, is made in the vicinity of the armature c , will that sound be transmitted and heard at the receiver of the instrument when the armatures c , h , of the two instruments, A, I, are not normally in unison with one another, as in case of some of the instruments illustrated in Fig. 6 of said patent?

Ans. If a loud sound of the same pitch as that of the tuned reed c , Fig. 5, is made in the vicinity of the reed, the reed c will be thrown sympathetically into vibration, and electrical undulations will thereby be created on the circuit $g b e f g$, which will correspond in form to the vibration of the reed c , but not necessarily to the form of the aerial sound vibration that originated the vibration of the reed c . For this reason, whatever sound might be produced by the receiving reed under given circumstances, while it might have the pitch of the loud sound actuating the reed c , it would not necessarily have the quality or *timbre* of that sound.

In the case considered, the reed of the receiver is of a different pitch from that of the transmitter, and is therefore not well adapted

to be set in vibration by that transmitter. As the reed of the receiver has a tendency to vibrate at a definite rate of its own, the electrical undulations transmitted, so far from tending to throw the reed of the receiver into vibration, tend to check the reed and stop its motion. Under such circumstances, it is extremely doubtful whether any sound at all would be perceived from receiving instruments arranged as in Fig. 6, with the reeds free and undamped by pressure against the ear; but if any sound should be perceived, it would be similar in pitch to the loud sound actuating the reed of the transmitter, but certainly different in quality.

Cross-Int. 842. Can the tendency of the flat plate *c* to vibrate at a definite rate of vibration of its own be checked or prevented by confining its ends, as in Fig. 7 of your patent of March 7, 1876, and Fig. 2 of your patent No. 186,787?

Ans. The plate of Fig. 2 of my patent No. 186,787 is not a steel reed like the armature *c*, Fig. 5, of my patent No. 174,465, of March 7, 1876, as assumed in the question. In the case of the armature *c*, Fig. 7 of my patent No. 174,465, the tendency of the steel reed to vibrate at a rate of its own is checked and prevented by fastening the armature loosely by one extremity to the uncovered leg *d* of the electro-magnet *b*, Fig. 7, and by attaching its other extremity to the centre of a stretched membrane *a*, as stated in the patent.

Cross-Int. 843. I wish you would examine the book of Reis and Bourseul* publications, put in evidence by the defendants December

* M. Charles Bourseul printed in Vol. XXIV. of "*L'Illustration*," Paris, Aug. 26, 1864, an article of several pages, in which he discussed some of the results which at that time had been obtained by various forms of electric telegraph. He predicted as a certainty that "in a more or less distant future, speech will be transmitted by electricity," and he said that he had made experiments which promised favorable results. He did not describe any of his experiments. His conception, however, as he outlined it, was an apparatus which was to work by making and breaking connection with a battery. Bourseul was, therefore, no nearer to success than Reis.

The Bourseul article, referred to, was frequently set up by defendants in the telephone litigation, and several versions of it were produced.

These Bourseul publications, some five in number, together with publications about Reis's work, of which there were about fifty, were, for the convenience of courts and counsel, collected and printed in a pamphlet of one hundred and twelve pages, which was known as the "Reis and Bourseul Publications," and is the book alluded to in the question.

2, 1891, and specify those of them which were known to you prior to the seventh day of March, 1876.

Ans. It is impossible for me now to distinguish those publications that were known to me before March 7, 1876, from those that I saw afterwards. I can only, therefore, answer your question in the most general way. Before March 7, 1876, I saw the complete Reis apparatus which Professor Henry had at the Smithsonian Institution. I had also read some publications referring to Reis, but I cannot say now what they were; I can only say in a general way that I had read little upon the subject before the date of my patent. My paper of May 10, 1876, shows the state of my knowledge relating to the Reis publications at that date. By that date, I had obtained the names of all the articles referred to in the paper; and very shortly after that date, I hunted up such of the articles and books as I could find in the libraries of Boston. The German articles I was unable to read, but looked over the illustrations; the French and English articles I could read. My paper of May 10, 1876, therefore, will answer your question more fully than I can do now from memory alone.

Cross-Int. 844. Please specify all those publications referred to in my last question that were known to you prior to the fifteenth day of January, 1877, if you are able so to do.

Ans. I am unable to answer the question, and can only say that such of the publications as are referred to in my paper of May 10, 1876, and which were in the libraries of Boston in the year 1876, had probably been looked at by me before January 15, 1877.

Cross-Int. 845. Do you find among the illustrations of the Reis apparatus contained in the pamphlet containing the Reis and Bourseul publications referred to, any which you remember to have seen prior to January 15, 1877?

Ans. I have no doubt I saw some of the illustrations referred to prior to January 15, 1877; but I am sure I cannot say now which they were.

Cross-Int. 846. If you intended to claim a method or art of transmitting articulate speech in your patent of March 7, 1876, No. 174,465, and also an apparatus or instrument for transmitting articulate speech, will you please specify and point out the claims in which

you intended to claim such an art or process, and the claims in which you intended to claim such an apparatus or instrument.

Ans. I intended to claim a method or art of transmitting vocal or other sounds telegraphically, including articulate speech, and also an apparatus or instrument for practising the art, in the 5th claim of my patent of March 7, 1876, No. 174,465. All the other claims of the patent include the subject-matter of the 5th claim, but they also include more. Claims 1, 2, 3 and 4 refer to undulatory currents of electricity generally, and to the apparatus of both Fig. 5 and Fig. 7. The 5th claim is more limited in its scope, and refers to the apparatus of Fig. 7 alone, and to a particular kind of undulatory current in which the electrical undulations are similar in form to the vibrations of the air accompanying the vocal or other sounds that we desire to transmit.

Cross-Int. 847. I notice that in your patent No. 186,787, of January 30, 1877, you state: "It is important that the distance of the magnet from the plate should be as little as possible, without, however, being in contact." Why was this suggestion as to the distance of the magnet from the plate made in the patent referred to, instead of in your patent of March 7, 1876?

Ans. The patent of March 7, 1876, did not have a plate like that referred to in the passage you have just read; but if the word "plate" be taken in the sense of armature, the reason why such an expression was not included in the patent of March 7, 1876, was, that I myself wrote that specification, and it was not my intention to describe specifically in that patent what was already well known in the arts.

Cross-Int. 848. You mean by your last answer, do you, that the means for adjusting the relative position of an electro-magnet and an armature was well known in the art prior to any invention claimed in your patent of March 7, 1876?

Ans. I meant that it was well known in the art that an armature in order to be operative should be well within the field of attraction of its magnet; and that the nearer the armature is to the pole of the magnet, the more powerfully will it operate.

Cross-Int. 849. In the specification of your patent No. 186,787, dated January 30, 1877, you say:

"My invention has for its object, first, the transmission simultaneously of two or more musical notes or telegraphic signals along a single wire in either or both directions, and with a single battery for the whole circuit, without the use of as many instruments as there are musical notes or telegraphic signals to be transmitted; second, the electrical transmission by the same means of articulate speech and sound of every kind, whether musical or not; third, the electrical transmission of musical tones, articulate speech, or sounds of every kind, without the necessity of using a voltaic battery."

Were these three objects thus referred to, also the objects of the inventions which you intended to claim in your patent of March 7, 1876?

Ans. The invention referred to in the passage quoted is an improved form of apparatus which is not found in my patent of March 7, 1876, No. 174,465. The objects referred to consist of results obtained by the employment of an improved electric telephone substantially like that described and claimed in my patent of January 30, 1877, No. 186,787.

Cross-Int. 850. In your preliminary statement in the Speaking Telephone Interferences, to which you have referred in your answer to Interrogatory 220, you say :

"I had previously seen in the Institute of Technology, in Boston, the receiving instrument of Reis's telephone; and was acquainted with the construction of the whole apparatus by diagrams and printed descriptions, but I had never before seen the transmitting portion of the apparatus."

To what particular diagrams and printed descriptions did you refer in this preliminary statement?

Ans. I cannot tell now. They were probably included in the printed descriptions referred to in my paper of May 10, 1876.

Cross-Int. 851. In your answer to Question 200, you say that people at a considerable distance away from the receiving instrument could hear Mr. Watson's voice. About what distance did you mean to indicate by the word "considerable"?

Ans. I meant that while it was necessary to place the ear close to the telephone in order to hear distinctly what was said, still, people standing near could catch the tones of the voice even at some considerable distance away. I do not know that I can define exactly what I mean by a "considerable" distance away, excepting in a

general way. For example, all the people in a room or small hall might be able to hear the tones of the voice, though they would not be able to understand what was said.

Cross-Int. 852. You say, in answer to Question 206, that you intended to give Professor Peirce credit for the difference between the combined cover and mouth-piece, shown in Fig. 29* of your London lecture, and the cover and projecting mouth-piece devised by you and described by you in your answer to Interrogatory 204. What was this difference to which you refer, and what was there in it that entitled it to credit?

Ans. Professor Peirce and the other gentlemen associated with him, to whom I alluded in my London lecture, viz, Professor Eli W. Blake, Doctor Channing, Mr. Clark and Mr. Jones, were certainly deserving of credit for the very generous and disinterested way in which they communicated to me the results of their experiments, with no other object than that of helping me to make my invention as perfect as possible. This was the reason I desired to give them all the credit I could possibly do consistently with my own researches. I understood from them that the form of mouth-piece shown in Fig. 29 of my London lecture had been invented by Professor Peirce, and I therefore desired to give him all the credit I could for it. The cover and projecting mouth-piece devised by me, and described in my answer to Interrogatory 204, consisted of a cover with a separate and distinct mouth-piece attached to it; whereas the cover of the telephone shown in Fig. 29 of my London lecture was both a cover and mouth-piece in one, and besides was of more convenient shape.

Cross-Int. 853. I understand you to state, in answer to Question

* Fig. 29 of the London lecture.

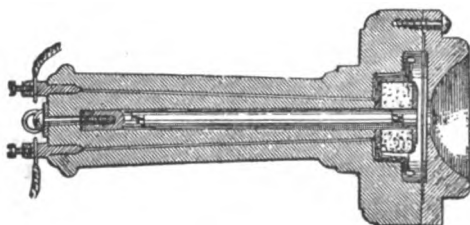


Fig. 29.

219, that it was stated that it might be possible to make the Reis instrument talk by taking advantage of the variable-resistance method used in the microphone and in carbon transmitters, and claimed by you in your patent No. 174,465. What particular claim of the patent No. 174,465 did you refer to in that answer?

Ans. I referred to the variable-resistance mode of carrying out Claim 5 of my patent of March 7, 1876, No. 174,465; that is, to Claim 4, so far as it refers to the method and apparatus of Claim 5. Claim 4 related to a variable-resistance mode of producing undulations suitable for use in the inventions illustrated both by Fig. 5 and Fig. 7 of the patent. I referred to the variable-resistance mode of Claim 4, so far as it related to the invention illustrated in Fig. 7; that is, so far as it related to the art or method of transmitting vocal or other sounds telegraphically, by causing electrical undulations similar in form to the vibration of the air accompanying the said vocal or other sounds which is claimed in Claim 5.

Cross-Int. 854. Having reference to your last answer, and other answers made by you, do you take the ground that the method of electrical communication between the transmitting and receiving instruments of the Reis apparatus as described in any printed publication published prior to the date of your patent No. 174,465 — so far as you have any knowledge or belief in respect to such publication or the contents thereof — taken in connection with all that is described and claimed in your two patents No. 174,465 and No. 186,787, was sufficient at the date of the last-named patent to enable a person skilled in the arts of acoustics and electricity to transmit intelligible speech with the Reis apparatus?

Ans. I am not sure that I quite understand the purport of your question; but I may say in relation to the first part of the question, that I take the ground that all the experiments of Reis and others, and all the knowledge of persons skilled in the arts of acoustics and electricity, together with all the information contained in printed publications prior to March 7, 1876, as a matter of fact, failed to enable anyone to transmit intelligible speech with any apparatus at all, operated by electricity, until I showed how it could be done in my patent of March 7, 1876, No. 174,465.

In regard to the second part of the question, I take the ground

that the knowledge disclosed in my two patents, No. 174,465 and No. 186,787, was sufficient, at the date of the last-named patent, to convince persons skilled in the arts of acoustics and electricity that it was impossible to transmit intelligible speech with the Reis apparatus; by showing that the defect lay in the very principle or mode of operation, so that no change or improvement in the form of apparatus alone could possibly enable the Reis apparatus to transmit articulate speech.

Cross-Int. 855. What was there about my last question that you did not understand? I should be pleased to put it in a different form, if I can know your views in regard to it.

Ans. I merely meant by my opening remark, that I desired to be responsive. I have answered the question according to my understanding of it, and if I have failed to understand in any degree, I should be glad to have you make your meaning clear to me by another question.

Cross-Int. 856. I gather from your answer to Interrogatory 854 that a person would know from the information imparted by your patents referred to, that the Reis instrument as it had existed prior to the date of your patents was incapable of transmitting articulate speech. What I wanted to know was, in view of your previous answers in this case, whether a person skilled in the arts of acoustics and electricity would obtain information from your patents referred to, from which he could operate the Reis telephone in such a manner as to cause it to transmit articulate speech.

Ans. No; he would not.

Cross-Int. 857. In your letter to Mr. Gray of March 2, 1876, you say:

"I do not know the nature of the application for a caveat, to which you have referred as having been filed two hours after my application for a patent, excepting that it had something to do with the vibration of a wire in water, and therefore conflicted with my patent."

When did you first learn that Gray's caveat had something to do with the vibration of a wire in water?

Ans. On February 19, 1876, my application filed February 14, 1876, had been declared to interfere with a pending caveat, and my

solicitors were therefore notified that my application would be suspended for ninety days; but on February 25, 1876, my solicitors were notified that the interference had been declared under a misapprehension of my rights, and the suspension of the application was withdrawn. During this period I was not in Washington, but I arrived there on Saturday, February 26, and of course I was anxious to know what the point of interference had been. I therefore took the opportunity, while in the Patent Office on the business described in answer to Interrogatory 108, of asking the Examiner what the point of interference had been, and in reply he pointed to the variable-resistance clauses in the body of the specification of my application, declining to give any more definite information, as a caveat, he said, was a confidential document. I carried away the impression that the exact point of interference had lain with that part of my application where I speak of vibrating the conducting wire in mercury or other liquid included in the circuit. I do not now remember whether the Examiner pointed to that sentence in my application, or whether I pointed it out to him and asked him whether that was the point of interference; but, at all events, I carried away the impression that it was, and that was all the information I obtained upon the subject. This happened either on Monday, February 28, 1876, or on Tuesday, February 29, 1876; I cannot be sure now.

Cross-Int. 858. What was the name of the Examiner to whom you referred in your last answer?

Ans. Mr. Z. F. Wilber.

Cross-Int. 859. When did you first become acquainted with Mr. Wilber, as nearly as you recollect?

Ans. I never became acquainted with him so as to know him by sight. I think I saw him for the first time in Washington, in February, 1875.

Cross-Int. 860. On how many different occasions did you meet him at the Patent Office, if you recollect?

Ans. I think only once, but cannot be quite sure.

Cross-Int. 861. And that once was, of course, the occasion to which you have referred in your testimony this morning?

Ans. Yes.

Cross-Int. 862. Who else was present — if you recollect — on the one occasion that you met Mr. Wilber at the Patent Office?

Ans. I did not know the people. Mr. Pollok or Mr. Bailey, or some person from Mr. Pollok's office, took me up there, and introduced me to Mr. Wilber, and then left me with him. There were some people, I think, in the office, but I do not remember with distinctness. All the people I saw there were strangers to me.

Cross-Int. 863. Have you stated all the conversation that occurred on the occasion of this interview with Mr. Wilber? If you have not, please make the statement as complete as possible.

Ans. I think I have stated substantially all that occurred. I went to the Patent Office specially for the purpose of explaining to the Examiner the exact points of difference between my specification filed February 14, 1876, and an earlier specification of my own filed the year previously, on the twenty-fifth day of February, 1875. These points are specified in my answer to Interrogatory 108. The Examiner requested me to reduce my explanation to writing in the form of an amendment, which was accordingly done, and this amendment was filed on the twenty-ninth day of February, 1876. It contains the substance of our conversation, and as it is a contemporaneous document, I prefer to refer to it, rather than to give from memory alone an account of a conversation held with a man who is no longer living. I shall, however, be very glad to do my best to answer any specific question on the subject.

Cross-Int. 864. Did any conversation occur at any time between you and Mr. Wilber, or between your attorneys and Mr. Wilber, touching the capacity of any instrument invented by you to transmit articulate speech?

Ans. So far as my attorneys are concerned, I do not know; and I cannot say now, from memory alone, whether or not any conversation occurred between me and Mr. Wilber upon the subject.

Cross-Int. 865. If I understand your last answer correctly, so far as you recollect, you were never called upon by Mr. Wilber to demonstrate the capacity of any apparatus invented by you to transmit articulate speech; and so far as you know and have been informed, your attorneys were never called upon at any time to

demonstrate the capacity of any apparatus invented by you to transmit articulate speech?

Ans. Your question, I understand, refers to my patent of March 7, 1876, No. 174,465. Previously to the issuing of this patent, I am quite certain that neither I nor my attorneys were called upon to demonstrate by experiment the capacity of my apparatus to transmit articulate speech, although it is perfectly possible, nay more than this, probable, that verbal demonstrations were made both by me and by my attorneys. I know that no experimental demonstration was called for, for the following reason: My patent of March 7, 1876, No. 174,465, was filed in the Patent Office on the fourteenth day of February, 1876, without my knowledge, and my attorneys did not have models in their possession whereby to illustrate the matters contained in the specification. When, therefore, I went to Washington I asked my attorneys about models, and I learned from them that that matter was already settled, and that the Commissioner of Patents had not required models in the case of my application. As the models were dispensed with, I know that neither I nor my attorneys were called upon for experimental demonstration.

Cross-Int. 866. Prior to March 7, 1876, were you represented before the Patent Office by any person, attorney in fact, or counsel, besides Messrs. Pollok & Bailey?

Ans. No.

Cross-Int. 867. Did you answer the letter of Professor Dolbear, referred to in your answer to Question 233?

Ans. Not so far as I remember.

Cross-Int. 868. At whose invitation was Professor Dolbear present at the interview mentioned in Question 235?

Ans. The invitation either of Mr. Hubbard or myself; I do not now remember.

Cross-Int. 869. In the specification of your patent No. 186,787, you use the following language:

“this instrument is and may be used both as a transmitter and as a receiver — that is to say, the sender of the message will use an instrument in every particular identical in construction and operation with that employed by the receiver, so that the same instrument can be used alternately as a receiver and a transmitter.”

Having reference to Fig. 5 of your patent No. 174,465, is it a fact

that the sender of a message will use an instrument in every particular identical in construction and operation with that employed by the receiver, so that the same instrument can be used alternately as a receiver and transmitter?

Ans. In the passage you have quoted from my patent of January 30, 1877, No. 186,787, the "instrument" referred to is an electric telephone. In reference to my patent No. 174,465, the apparatus of Fig 5 is not an electric telephone at all, and cannot be used either as a telephonic transmitter or receiver, for the transmission of articulate speech, as arranged in Fig. 5. The apparatus of Fig. 5 illustrates one pair of a series of instruments used for the purposes of multiple telegraphy; and while it might be possible, by plucking the reed *c*, to cause a musical tone from the reed *h*, and conversely, by plucking the reed *h*, to cause a musical tone from the reed *c*, with the instruments precisely alike in every respect, still they were not intended so to be used. The transmitting reed *c* was intended to be arranged in a metallic bed, and connected with a wind-chest or bellows so that it could be blown by wind; whereas the reed of the receiver was intended to be free and to work a vibratory circuit-breaker, and make and break a local circuit containing a Morse sounder, register, or other telegraphic apparatus.

Cross-Int. 870. Please answer the same question with reference to Fig. 7 of your patent No. 174,465.

Ans. In relation to Fig. 7 of my patent No. 174,465, I may say, that while, of course, each instrument could be used alternately as a transmitter and as a receiver, I thought the effect would be improved by employing the cone *A* when the instrument was used as a transmitter, and a hearing-trumpet *L* when it was used as a receiver.

Cross-Int. 871. In your patent No. 186,787, you use the following language:

"In lieu of the plate *A* in above figures, iron or steel reeds of definite pitch may be placed in front of the electro-magnet *O*, and, in connection with a series of such instruments of different pitches, an arrangement upon circuit may be employed similar to that shown in my patent No. 174,465, and illustrated in Fig. 6 of Sheet 2 in said patent. The battery, of course, may be omitted."

Did you intend the word "figures" in the paragraph quoted to refer to all the figures of the patent, or only some of them?

Ans. I did not write this specification myself, and I do not know, therefore, precisely what my attorneys meant to refer to by the word "figures." The word certainly refers to Fig. 5 and Fig. 6; I do not know whether it was intended to include all the other figures or not.

Cross-Int. 872. When you wrote the specification of your patent No. 174,465, did you intend that there should be any limitation as to the number of instruments for transmitting vocal or other sounds telegraphically joined upon the same circuit, or did you intend to join on a single circuit but two instruments, as illustrated in Fig. 7?

Ans. I did not intend to limit the number of telephonic instruments, like those shown in Fig. 7, to be used upon the same circuit. Two are shown in Fig. 7 because I desired in that figure to show a complete telephone, which, of course, cannot consist of less than two instruments and a circuit between.

Cross-Int. 873. Does the apparatus illustrated in Fig. 7 of your patent No. 174,465, as intended by you when you prepared the specification, show the union upon and by means of an electric circuit of two or more instruments so that if motion of any kind or form be produced in any way in the armature of any one of the said instruments, the armatures of all the other instruments upon the same circuit will be moved in like manner and form, and if such motion be produced in the former by sound, like sound will be produced by the motion of the latter?

Ans. Yes; but the instruments of Fig. 7 of my patent No. 174,465 are different from those shown in my patent of January 30, 1877, No. 186,787, which contains in the first claim the language of your question, with the exception of a single phrase. After the words: "The union upon, and by means of, an electric circuit of two or more instruments," comes the following phrase which you have not quoted: "constructed for operation substantially as herein shown and described." The claim refers to telephones constructed for operation substantially as shown and described in my patent of January 30, 1877, No. 186,787, and not to telephones like those described in my patent of March 7, 1876, No. 174,465, and illustrated in Fig. 7.

Cross-Int. 874. In case the instrument shown in Figs. 1, 2, 3,

4, 5 and 6 of the drawings of your patent No. 186,787 was constructed in accordance with the paragraph from the specification quoted in my question No. 871, how would it differ in its electrical mode of operation from the apparatus shown in Fig. 5 of your patent No. 174,465?

Ans. In this case, the removal of the diaphragm armature or plate A shown in the drawings of my patent No. 186,787, and the substitution for it of a tuned steel reed like *c* of my patent No. 174,465, would convert the instrument from an electric speaking telephone into a multiple-telegraph instrument. It would then constitute a multiple-telegraph instrument differing in the details of construction from that shown in Fig. 5 of my patent No. 174,465. The difference would be a difference in the form of apparatus, and not in the electrical mode of operation.

Cross-Int. 875. I notice that the words "electrical undulations" are used in each of the claims of your patent No. 174,465, but that no such words are used in the claims of your patent No. 186,787. Why is this?

Ans. My patent No. 186,787 was for an electric telephone of improved construction. My patent No. 174,465, of March 7, 1876, dealt broadly with the art or method of producing undulations like sound vibrations, and in it I claimed processes or methods for producing such undulations, and apparatus for carrying the processes into effect. In my patent No. 186,787, no new methods or processes were shown, but only improvements in the construction of the apparatus for transmitting vocal or other sounds telegraphically, shown in Fig. 7 of my patent of March 7, 1876, No. 174,465.

Cross-Int. 876. In the second claim of your patent No. 186,787 you use the following introductory language: "In a system of electric telegraphy or telephony." Did you intend from this language that the invention therein claimed should have application either to a system of multiple harmonic telegraphy, or to a system of telephony, or to both systems?

Ans. Of course, I did not draw the claim myself, and cannot, therefore, say exactly what my attorneys meant by the language employed. I understood the claim to refer to transmitting and receiving instruments constituting electric telephones (the receiving

instruments being substantially like those shown and described in the patent No. 186,787), and to their use in such systems of communication as are referred to in the patent, whether you term them systems of telegraphy or telephony. At the time this specification was written, the word "telephony" had not become a recognized term in the art. In the commencement of my specification I entitled the inventions shown in the patent No. 186,787, "Improvements in Electric Telephony," alone; but in the Patent Office the patent was styled "Improvement in Electric Telegraphy." In Claim 2 both words are employed indifferently, so that there shall be no misunderstanding. Claim 2 refers to systems of telegraphy or telephony, whichever you choose to call them, in which electric telephones are used like those described in my patent No. 186,787.

Cross-Int. 877. Having reference to your patent No. 186,787: How does the invention which you intended to claim in Claim 1 of that patent, at the time you took oath to the invention, differ from the invention which you intended to claim in Claim 2 of the same patent?

Ans. Claim 1 refers to the use of electric telephones like those shown in the patent, both as transmitters and receivers upon a magneto-electric plan like that shown in Fig. 4 or Fig. 6. Claim 2 refers to the use of electric telephones like those shown in the patent, as receiving telephones alone, independently of the form of transmitter employed. I understood this claim to refer specially to the use of the telephone with variable-resistance transmitters like those described in Volume XII. of the Proceedings of the American Academy of Arts and Sciences, to which I made reference in the specification. The reference alludes to my paper of May 10, 1876, already in evidence in this case.

Cross-Int. 878. How did the invention which you intended to claim in Claim 2 of your patent No. 186,787, at the time you made oath to the invention, differ in its electrical mode of operation from the invention which you intended to claim in Claim 1 of your patent No. 174,465?

Ans. Both claims refer to the same electrical mode of operation; but Claim 2 of my patent No. 186,787 was limited to the use of

receivers constituting electric telephones like those shown in the patent No. 186,787.

Cross-Int. 879. Claim 5 of your patent No. 186,787 is as follows :

“The formation, in an electric telephone such as herein shown and described, of a magnet with a coil upon the end or ends of the magnet nearest the plate.”

Did you, at the time you made oath to the invention, intend that the words “a coil upon the end or ends of the magnet nearest the plate” should mean a coil placed in the position shown in Figs. 2 and 3 of the drawings of the patent?

Ans. I intended that the words should be applicable to all the drawings of the patent in which any coil is shown; that is, to Figs. 2, 3, 4, 5 and 6.

Cross-Int. 880. Please point out all parts of the specification and all figures of the drawings in which the sounding-box referred to in Claim 6 is illustrated or described.

Ans. The sounding-box or cover referred to in Claim 6 is shown at D in Figs. 1, 2 and 3, and is described in that part of the specification that refers to Figs. 1, 2 and 3.

Cross-Int. 881. When did you first know of the application of a sounding-box to a telephone of any kind? You will note that my question is not confined to telephones which you deem to be applicable to the transmission of speech.

Ans. I am sure I do not know. The receiving instrument of the Reis apparatus had a sounding-box attached, but I do not think it constituted a cover. Of course Claim 6 of my patent No. 186,787 referred to the use of a sounding-box substantially like that shown in Figs. 1, 2 and 3, in an electric telephone like that described in the patent itself.

Cross-Int. 882. When did you first know of the employment of a speaking or hearing-tube for conveying sounds to or from a telephone of any kind, using the word “telephone” in the same generic sense as before?

Ans. I am sure I do not know. The transmitting instrument of the Reis apparatus had a tube for conveying sounds to the membrane, but there was no tube of this kind on the receiver. Of course Claim

7 of my patent No. 186,787 is limited to the employment of speaking or hearing-tubes in electric telephones like those described in that patent.

Direct Examination resumed.

Int. 883. Ever since the beginning of the manufacture in May, 1877, by the owners of your two patents, No. 174,465 and No. 186,787, of electric speaking telephones for commercial use, has any provision been made in any of those telephones for changing the adjustment of the position of the diaphragm relatively to the pole of the electro-magnet?

Ans. No. The relative position of the diaphragm and the pole of the electro-magnet was adjusted once and for all, at the time of manufacture, and fixed in that position so that no one could afterwards alter it.

Int. 884. There has been put in evidence the description of your experiment with electric speaking telephones upon the telegraph line of the Walworth Manufacturing Company, on the evening of October 9, 1876, published in the *Boston Daily Advertiser* of October 19, 1876. Was there in the same issue of that newspaper an editorial upon the subject, and, if so, have you a copy of the same which you have compared with the original?

Ans. There was such an editorial, and I hold in my hand a copy of it which I have compared with the original.

[*Counsel for defendants puts in evidence the copy just referred to by the witness, and it is marked "Defendant's Exhibit Boston Advertiser Editorial of October 19, 1876, H. L. H., Special Examiner."*]

Int. 885. In Cross-interrogatory 305, counsel for complainant justified his application of the word "telephone" to the instrument first known in this country as the "lovers' telegraph," or the "thread telegraph," on what he supposed to be the excellent authority of Sir Charles Wheatstone, and, in support of that supposition, he quoted from what he styled "Preece's book, *The Telephone*," the following:

"In the 'Repository of Arts of September 1, 1821, we read a description of an instrument which Wheatstone invented, and called a 'telephone.'"

The full title of the book so referred to by counsel for complainant is "*The Telephone*." By William Henry Preece, F. R. S., and Julius Maier, Ph. D." And the title page also shows that it was published in London and New York in 1889. The quotation is upon page 2 of the book. Have you examined the *Repository of Arts* referred to in the quotation; and is there any justification therein for the statement that Wheatstone called his instrument "a telephone"?

Ans. I have examined the *Repository of Arts* for September 1, 1821, in the library of the Boston Athenæum, without finding any justification for the statement quoted. The instrument which Wheatstone invented was there termed "The Enchanted Lyre," and neither the word "telephone" nor any derivative thereof, like "telephony" or "telephonic," occurs in the article.

Int. 886. Are you acquainted with Mr. William Henry Preece, one of the authors of the book referred to; and if so, when did you first know him?

Ans. Yes; he called upon me in Cambridge, Mass. I do not remember the exact date; I think it was either late in 1876, or early in 1877; I knew him subsequently also in England.

Int. 887. What position did Mr. William Henry Preece occupy at that time; and what was his reputation as a scientific man?

Ans. He was the Superintendent of the Postal Telegraph System of Great Britain; and he was considered an authority upon matters relating to electricity and telegraphy.

Int. 888. In the *Popular Science Review*, a periodical published in England in the year 1877, under the head of *Scientific Summary*, and the sub-title *Physics*, is an article which begins as follows:

"*The Telephone*."—During the recent session of the British Association at Plymouth, the lion's share of attention was unquestionably given to the telephone. Wherever the instrument was to be exhibited—whether in the Physical or in the Mechanical sections, or at Mr. Preece's popular evening lecture—there were always crowded audiences eager to learn something about so novel an apparatus. At the *soirées*, too, the telephone stood above everything else as the centre of attraction; and knots of people were crowded round the instrument, anxious to converse with friends in distant apartments. The interest in this subject culminated in the arrival of Professor Graham Bell, the inventor of the 'talking telegraph.'"

Did the events thus narrated come within your own personal knowledge; and if so, will you briefly state the circumstances?

Ans. Yes. In August, 1877, I was in Glasgow, Scotland, about the time of the meeting of the British Association in Plymouth, England, and I received an invitation to attend the meeting. Upon arrival in Plymouth I found that the telephone seemed to be the great attraction there; and the statement you have quoted from the *Popular Science Review*, I think was justified by the facts.

Int. 889. Was the Mr. Preece mentioned in the quotation from the *Popular Science Review*, made in the last preceding interrogatory, Mr. William Henry Preece whom you have referred to?

Ans. Yes.

[*Counsel for defendants puts in evidence a copy of the article on "The Telephone" published in the Popular Science Review of 1877, and it is marked "Defendants' Exhibit Popular Science Review Article of 1877, H. L. H., Special Examiner."*]

Counsel for defendants also puts in evidence a copy of an article published in the London, Edinburgh and Dublin Philosophical Magazine and Journal of Science, April, 1878, entitled "On some Physical Points connected with the Telephone. By William Henry Preece, Vice-President of the Society of Telegraph Engineers, Memb. Inst. C. E., &c." and the same is marked "Defendants' Exhibit Preece's Telephone Article of April, 1878, H. L. H., Special Examiner."]

Int. 890. In Cross-interrogatory 354, quotation is made from Prescott's book about the telephone, of an extract which purported to be taken from the *Westminster Review*. Can you identify that article; and if so, what was the date of its publication?

Ans. Yes; it is contained in an article entitled "*The Telephone*," published in the *Westminster and Foreign Quarterly Review*, January 1, 1878.

[*Counsel for defendants puts in evidence a copy of the article just referred to by the witness, and it is marked "Defendants' Exhibit Westminster Review Article of January, 1878, H. L. H., Special Examiner."*]

Int. 891. In your answer to Cross-interrogatory 450, you mention an article published in *The Commonwealth*, on Saturday,

November 14, 1874, relating to Elisha Gray's inventions. Have you a copy of that article which you have verified by comparison with the original; and if so, will you produce it?

Ans. Yes; and I produce it.

[*Counsel for defendants puts in evidence a copy of the article just referred to by the witness, and it is marked "Defendants' Exhibit Boston Commonwealth Article of November 14, 1874, H. L. H., Special Examiner."*]

Int. 892. In Cross-interrogatory 482, counsel for complainant read from the printed record in the case of *American Bell Telephone Company et al. v. The People's Telephone Company et al.* a copy of a letter which you wrote to your parents, March 5, 1875. In that letter reference was made to knowledge which Mr. Orton, President of the Western Union Telegraph Company, had of Elisha Gray's inventions, and also to knowledge which your solicitors, Messrs. Pollok & Bailey, had of the same inventions. What public communication of such knowledge had Elisha Gray himself made, so far as you know, besides that contained in the *Boston Commonwealth* article of November 14, 1874.

Ans. In February, 1875, while in Washington, Mr. Orton informed me that Mr. Elisha Gray had exhibited his musical telegraph apparatus to him, and I understood from my solicitors, Messrs. Pollok & Bailey, that Mr. Gray's apparatus had been publicly exhibited in Washington. I have here before me a certified copy from the records of the Patent Office of the preliminary statement of Elisha Gray, filed April 28, 1876, in the matter of the interference between his application of February 23, 1875, my application of February 25, 1875, and the application of Paul La Cour, filed March 3, 1875. In this preliminary statement, Elisha Gray said:—

"During the month of April, 1874, I experimented upon the best method of transmitting a tone. Among them I employed a reed of an ordinary melodeon which was operated by air. I also commenced a mechanical transmitter having an octave of tones, which transmitter was operated by clock-work, but finally adopted my first method of vibrating a tuned-bar by means of electricity, which method I have used ever since. I immediately constructed a transmitter with a series of eight tones arranged to a diatonic scale.

About the first of May, 1874, I went to New York where I exhibited this apparatus to a number of persons at the Western Union and Gold and Stock Telegraph Company's building.

After my first experiment I made no secret of my invention but explained it to everyone who wished to see it. During the month of May, 1874, I went to Washington and exhibited my apparatus in the Smithsonian Institute, before Professor Henry, Mr. Z. F. Wilber, the Examiner in charge of this class in the Patent Office, and others; I also exhibited it in the Western Union Telegraph building in that city in the presence of some of the operators."

"The application now in interference was filed on the 23d of February, 1875, but the specification was sworn to on the ninth day of January, 1875, having been prepared some days before, and the models were completed in December, 1874, and the apparatus exhibited in Chicago to the Hon. William Orton, President of the Western Union Telegraph Company.

Other operative machines, but not so nicely finished as these models, were made and used during the preceding month.

To conduct my experiments with greater facility, I connected the shop where I was working with the Western Union line, and worked my apparatus through long circuits from time to time."

"My invention and experiments during 1874-5, were not only matters of notoriety among professional telegraphers, but were noticed at various times in the papers and periodicals, and were frequently exhibited and explained by me in public not only as a matter of amusement, but before scientific associations, and persons engaged in the management of the various telegraph lines of the country."

Int. 893. You have stated that you testified in the suit of *Bell Telephone Company v. Peter A. Dowd*, and in the suit of *American Bell Telephone Company et al. v. The People's Telephone Company et al.* Was the substance of your testimony in the present deposition contained in your former depositions in those suits?

[*Objected to as irrelevant and incompetent, and calling for new matter not referred to the direct examination of the witness.*]

Ans. Yes.

[*Counsel for defendants puts in evidence, from the English translation by Alexander J. Ellis, of the work of Professor Herman L. F. Helmholtz, entitled in the German "Die Lehre von den Tonempfindungen," etc., and rendered into English, "On the Sensations of Tone," etc., the description of Helmholtz's vowel apparatus contained*

in Chapter VI. and Appendix VIII. of that work, and the same is marked "Defendants' Exhibit Description of Helmholtz's Vowel Apparatus, H. L. H., Special Examiner."

Counsel for defendants also puts in evidence a certified copy of patent No. 178,399, dated June 6, 1876, and granted Alexander G. Bell for Improvements in Receivers for Electric Telegraphs, and the same is marked "Defendants' Exhibit Bell's Patent, No. 178,399, of June 6, 1876, H. L. H., Special Examiner."]

Cross-Examination resumed.

Cross-Int. 894 (*de bene*). I understand you to state in your answer to Question 893 that the substance of your testimony in the present deposition is contained in your former depositions in the suits of the *Bell Telephone Company v. Peter A. Dowd*, and of the *American Bell Telephone Company et al v. The People's Telephone Company et al*. Did you mean by your answer that all the facts stated in your present deposition are to be found in substance stated in your former depositions in the suits referred to?

Ans. Speaking from a general recollection of the present deposition and of the former depositions referred to, and from a knowledge of the facts, I may say that in my opinion the present deposition is substantially the former depositions over again. Of course, details may be elaborated here and there in a somewhat different manner, or to a greater or less degree, because the case has been handled by different counsel; but I do not think any material facts connected with the history of my invention are to be found in the present deposition that are not also to be found, in substance, in the former depositions referred to; and I must say that I have felt somewhat aggrieved that I should have been called upon, at this late date, at considerable expenditure of time and labor, and at great personal inconvenience to myself, to tell all over again the same old story I told in my former depositions, after it had been passed upon by the Supreme Court of the United States. However the present deposition may differ from the former ones referred to, it seems to me that in substance, and in all material respects, it is the same thing over again.

Cross-Int. 895 (*de bene*). Please examine the printed records

in the suits of the *Bell Telephone Company v. Peter A. Dowd*, and of the *American Bell Telephone Company et al. v. The People's Telephone Company et al.*, to which you have frequently referred on your direct examination, and designate by number all answers to questions propounded to you on your cross-examination in this cause which are to be found in those printed depositions, referring for the sake of clearness to the numbers of the questions and answers in all the depositions referred to.

Ans. I should be very glad to oblige you in this matter, but when I consider the magnitude of the task you impose upon me, I would rather not undertake the work. It seems to me that the comparison of these voluminous records is a matter for the Courts, and for counsel who are paid for the labor involved, to undertake; but I do not feel that I myself personally can be called upon to undergo the labor. I should very gladly see you put the whole of my former depositions into this case, so that comparison could be made by the Court itself. Of course, I am ready to answer any specific questions from my general recollection of the testimony given in former suits.

Cross-Int. 896 (*de bene*). I understand you to have stated to the Court in your answer to Question 893, that the substance of your testimony in the present deposition is contained in your former depositions, and in order that this answer should be intelligible to the Court, I have asked you to point out or designate by number all answers to questions propounded to you on your cross-examination in this cause, which are, as you have stated, contained in your former depositions. In so doing, I consider that I have simply called upon you to explain and render definite an answer which you have given upon your direct examination; and with this explanation, shall be obliged to ask you to answer the question to the best of your ability. You will note that my question calls for no explanation of your former testimony, or of your testimony in this cause, but simply a numerical designation of the answers made in this cause by you which are to be found in your former depositions; and you will also note that the question is confined to answers to questions propounded to you upon your cross-examination.

Ans. If your question called for only a moderate amount of labor

on my part, I should certainly be happy to do my best to oblige you ; but knowing as I do the voluminous nature of the records you ask me to examine, and knowing that such examination would require a considerable expenditure of time and labor upon my part, I cannot undertake the work. I do not understand that I can be called upon to undertake work that is more suitable for counsel to perform, and for which I have neither time nor inclination. The impression left upon my mind by the testimony I have been called upon to give in this case, is that the substance of my testimony in the present deposition is contained in the former depositions. That is my opinion, based simply upon a general recollection of my former depositions. Place all my former depositions in evidence in this case, and counsel and the Court can make comparisons for themselves.

Cross-Int. 897 (*de bene*). I understand you to state in answer to the last question, that you will, as an explanation of Question 893 and as an answer to the last two preceding questions, produce and offer the printed copies of your depositions in the suit of *Bell Telephone Company v. Peter A. Dowd*, and in the suit of *American Bell Telephone Company et al. v. The People's Telephone Company et al.* Is that so?

Ans. I am willing and anxious that the printed copies of my depositions should be put in evidence in this case.

[*Counsel for defendants states that he is willing to furnish to counsel for complainant printed copies of the depositions of Alexander Graham Bell in the suits of Bell Telephone Company v. Peter A. Dowd and American Bell Telephone Company et al. v. The People's Telephone Company et al., together with printed copies of such exhibits referred to in said depositions as are required for the proper understanding of the same, and to agree that such printed copies are correct, without the formality of certificates of the clerks of the courts to that effect. If counsel for complainant then desires to put such copies in evidence, counsel for defendants will offer no objection.*

In view of the answers of the witness to Question 893 and Cross-questions 894 to 897, inclusive, counsel for complainant accepts the proposition of counsel for defendants, and will ask that the depositions

*referred to be marked as exhibits in this cause when produced by counsel for defendants.]**

Cross-Int. 898 (*de bene*). Did you, before answering Question 893, make a careful examination of your depositions in the suit of *Bell Telephone Company v. Peter A. Dowd*, and in the suit of the *American Bell Telephone Company et al. v. The People's Telephone Company et al.*, with the object of ascertaining to what extent the facts testified to by you in the present cause were contained in said depositions?

Ans. I have examined the depositions recently, but not with the object specified, nor can I say that it was a particularly careful examination; I simply read through the two depositions referred to, shortly before I began to testify in this case, and I have not looked at them since, excepting so far as my attention may have been called to specific parts in the course of this deposition.

ALEXANDER GRAHAM BELL.

* Copies of the depositions referred to were produced and put in evidence, and are part of the original deposition.

A. G. BELL.
TELEGRAPHY.

No. 174,465.

Patented March 7, 1876.

Fig. 1

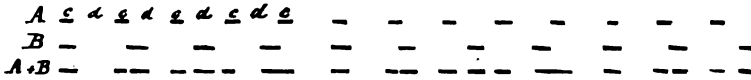


Fig. 2.

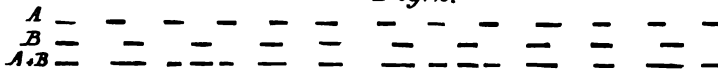


Fig. 3

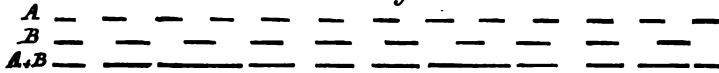


Fig. 4.

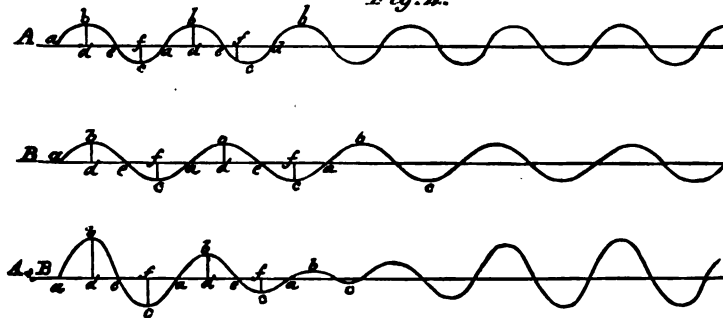
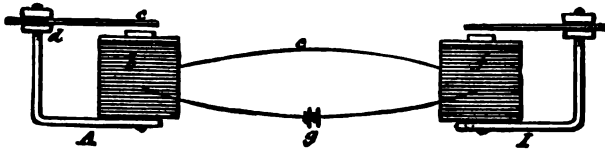


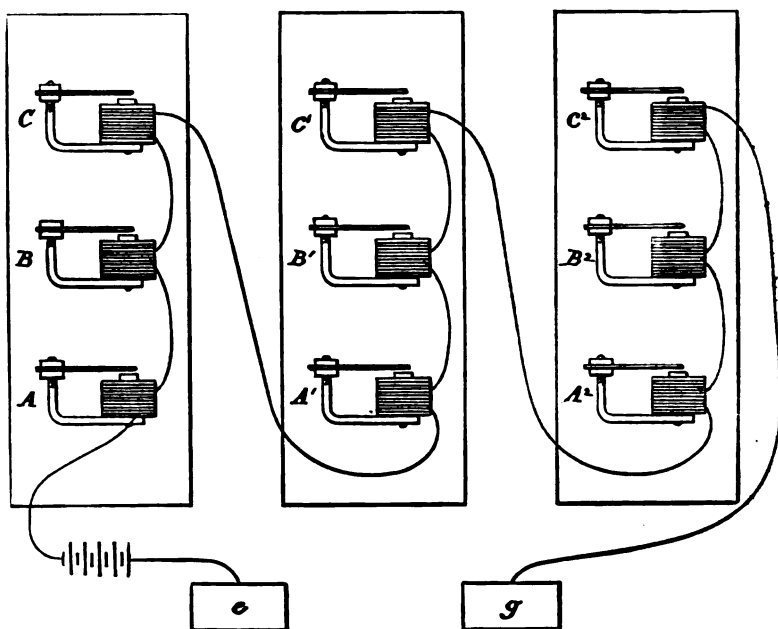
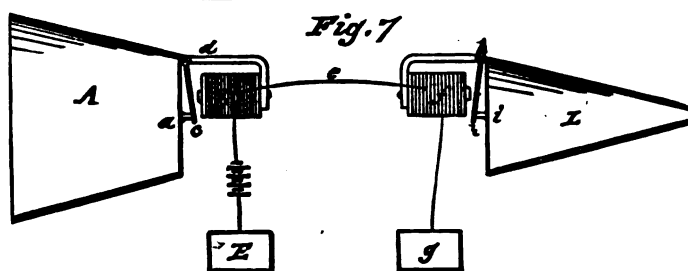
Fig. 5.



A. G. BELL.
TELEGRAPHY.

No. 174,465.

Patented March 7, 1876.

Fig 6.*Fig. 7*

UNITED STATES PATENT OFFICE.

ALEXANDER GRAHAM BELL, OF SALEM, MASSACHUSETTS.

IMPROVEMENT IN TELEGRAPHY.

Specification forming part of Letters Patent No. 174,465, dated March 7, 1876;
application filed February 14, 1876.

To all whom it may concern :

Be it known that I, ALEXANDER GRAHAM BELL, of Salem, Massachusetts, have invented certain new and useful Improvements in Telegraphy, of which the following is a specification :—

In Letters Patent granted to me April 6, 1875, No. 161,739, I have described a method of, and apparatus for, transmitting two or more telegraphic signals simultaneously along a single wire by the employment of transmitting instruments, each of which occasions a succession of electrical impulses differing in rate from the others; and of receiving instruments, each tuned to a pitch at which it will be put in vibration to produce its fundamental note by one only of the transmitting instruments; and of vibratory circuit-breakers operating to convert the vibratory movement of the receiving instrument into a permanent make or break (as the case may be) of a local circuit, in which is placed a Morse sounder, register, or other telegraphic apparatus. I have also therein described a form of autograph-telegraph based upon the action of the above-mentioned instruments.

In illustration of my method of multiple telegraphy I have shown in the patent aforesaid, as one form of transmitting instrument, an electro-magnet having a steel-spring armature, which is kept in vibration by the action of a local battery. This armature in vibrating makes and breaks the main circuit, producing an intermittent current upon the line wire. I have found, however, that upon this plan the limit to the number of signals that can be sent simultaneously over the same wire is very speedily reached; for, when a number of transmitting instruments, having different rates of vibra-

tion, are simultaneously making and breaking the same circuit, the effect upon the main line is practically equivalent to one continuous current.

In a pending application for Letters Patent, filed in the United States Patent Office February 25, 1875, I have described two ways of producing the intermittent current — the one by actual make and break of contact, the other by alternately increasing and diminishing the intensity of the current without actually breaking the circuit. The current produced by the latter method I shall term, for distinction sake, a pulsatory current.

My present invention consists in the employment of a vibratory or undulatory current of electricity in contradistinction to a merely intermittent or pulsatory current, and of a method of, and apparatus for, producing electrical undulations upon the line-wire.

The distinction between an undulatory and a pulsatory current will be understood by considering that electrical pulsations are caused by sudden or instantaneous changes of intensity, and that electrical undulations result from gradual changes of intensity exactly analogous to the changes in the density of air occasioned by simple pendulous vibrations. The electrical movement, like the aerial motion, can be represented by a sinusoidal curve or by the resultant of several sinusoidal curves.

Intermittent or pulsatory and undulatory currents may be of two kinds, accordingly as the successive impulses have all the same polarity or are alternately positive and negative.

The advantages I claim to derive from the use of an undulatory current in place of a merely intermittent one are, first, that a very much larger number of signals can be transmitted simultaneously on the same circuit; second, that a closed circuit and single main battery may be used; third, that communication in both directions is established without the necessity of special induction-coils; fourth, that cable despatches may be transmitted more rapidly than by means of an intermittent current or by the methods at present in use; for, as it is unnecessary to discharge the cable before a new signal can be made, the lagging of cable-signals is prevented; fifth, and that as the circuit is never broken a spark-arrester becomes unnecessary.

It has long been known that when a permanent magnet is caused to approach the pole of an electro-magnet a current of electricity is induced in the coils of the latter, and that when it is made to recede a current of opposite polarity to the first appears upon the wire. When, therefore, a permanent magnet is caused to vibrate in front of the pole of an electro-magnet an undulatory current of electricity is induced in the coils of the electro-magnet, the undulations of which correspond, in rapidity of succession, to the vibrations of the magnet, in polarity to the direction of its motion, and in intensity to the amplitude of its vibration.

That the difference between an undulatory and an intermittent current may be more clearly understood I shall describe the condition of the electrical current when the attempt is made to transmit two musical notes simultaneously — first upon the one plan and then upon the other. Let the interval between the two sounds be a major third; then their rates of vibration are in the ratio of 4 to 5. Now, when the intermittent current is used the circuit is made and broken four times by one transmitting-instrument in the same time that five makes and breaks are caused by the other. A and B, Figs. 1, 2, and 3, represent the intermittent currents produced, four impulses of B being made in the same time as five impulses of A. *c c c*, &c., show where and for how long time the circuit is made, and *d d d*, &c., indicate the duration of the breaks of the circuit. The line A and B shows the total effect upon the current when the transmitting-instruments for A and B are caused simultaneously to make and break the same circuit. The resultant effect depends very much upon the duration of the make relatively to the break. In Fig. 1 the ratio is as 1 to 4; in Fig. 2, as 1 to 2; and in Fig. 3 the makes and breaks are of equal duration. The combined effect A and B, Fig. 3, is very nearly equivalent to a continuous current.

When many transmitting instruments of different rates of vibration are simultaneously making and breaking the same circuit the current upon the main line becomes for all practical purposes continuous.

Next, consider the effect when an undulatory current is employed. Electrical undulations, induced by the vibration of a body capable of inductive action, can be represented graphically, without error,

by the same sinusoidal curve which expresses the vibration of the inducing body itself, and the effect of its vibration upon the air; for, as above stated, the rate of oscillation in the electrical current corresponds to the rate of vibration of the inducing body — that is, to the pitch of the sound produced. The intensity of the current varies with the amplitude of the vibration — that is, with the loudness of the sound; and the polarity of the current corresponds to the direction of the vibrating body — that is, to the condensations and rarefactions of air produced by the vibration. Hence, the sinusoidal curve A or B, Fig. 4, represents, graphically, the electrical undulations induced in a circuit by the vibration of a body capable of inductive action.

The horizontal line *a d e f*, &c., represents the zero of current. The elevations *b b b*, &c., indicate impulses of positive electricity. The depressions *c c c*, &c., show impulses of negative electricity. The vertical distance *b d* or *c f* of any portion of the curve from the zero line expresses the intensity of the positive or negative impulse at the part observed, and the horizontal distance *a a* indicates the duration of the electrical oscillation. The vibrations represented by the sinusoidal curves B and A, Fig. 4, are in the ratio aforesaid, of 4 to 5 — that is, four oscillations of B are made in the same time as five oscillations of A.

The combined effect of A and B, when induced simultaneously on the same circuit, is expressed by the curve A+B, Fig. 4, which is the algebraical sum of the sinusoidal curves A and B. This curve A+B also indicates the actual motion of the air when the two musical notes considered are sounded simultaneously. Thus, when electrical undulations of different rates are simultaneously induced in the same circuit, an effect is produced exactly analogous to that occasioned in the air by the vibration of the inducing bodies. Hence, the co-existence upon a telegraphic circuit of electrical vibrations of different pitch is manifested, not by the obliteration of the vibratory character of the current, but by peculiarities in the shapes of the electrical undulations, or, in other words, by peculiarities in the shapes of the curves which represent those undulations.

There are many ways of producing undulatory currents of electricity, dependent for effect upon the vibrations or motions of bodies

capable of inductive action. A few of the methods that may be employed I shall here specify. When a wire, through which a continuous current of electricity is passing, is caused to vibrate in the neighborhood of another wire, an undulatory current of electricity is induced in the latter. When a cylinder, upon which are arranged bar-magnets, is made to rotate in front of the pole of an electro-magnet, an undulatory current of electricity is induced in the coils of the electro-magnet.

Undulations are caused in a continuous voltaic current by the vibration or motion of bodies capable of inductive action; or by the vibration of the conducting-wire itself in the neighborhood of such bodies. Electrical undulations may also be caused by alternately increasing and diminishing the resistance of the circuit, or by alternately increasing and diminishing the power of the battery. The internal resistance of a battery is diminished by bringing the voltaic elements nearer together, and increased by placing them farther apart. The reciprocal vibration of the elements of a battery, therefore, occasions an undulatory action in the voltaic current. The external resistance may also be varied. For instance, let mercury or some other liquid form part of a voltaic circuit, then the more deeply the conducting-wire is immersed in the mercury or other liquid, the less resistance does the liquid offer to the passage of the current. Hence, the vibration of the conducting-wire in mercury or other liquid included in the circuit occasions undulations in the current. The vertical vibration of the elements of a battery in the liquid in which they are immersed produces an undulatory action in the current by alternately increasing and diminishing the power of the battery.

In illustration of the method of creating electrical undulations, I shall show and describe one form of apparatus for producing the effect. I prefer to employ for this purpose an electro-magnet *A*, Fig. 5, having a coil upon only one of its legs *b*. A steel-spring armature, *c*, is firmly clamped by one extremity to the uncovered leg *d* of the magnet, and its free end is allowed to project above the pole of the covered leg. The armature *c* can be set in vibration in a variety of ways, one of which is by wind, and, in vibrating, it produces a musical note of a certain definite pitch.

When the instrument A is placed in a voltaic circuit, $g b e f g$, the armature c becomes magnetic, and the polarity of its free end is opposed to that of the magnet underneath. So long as the armature c remains at rest, no effect is produced upon the voltaic current, but the moment it is set in vibration to produce its musical note a powerful inductive action takes place, and electrical undulations traverse the circuit $g b e f g$. The vibratory current passing through the coil of the electro-magnet f causes vibration in its armature h when the armature $c h$ of the two instruments A I are normally in unison with one another; but the armature h is unaffected by the passage of the undulatory current when the pitches of the two instruments are different.

A number of instruments may be placed upon a telegraphic circuit, as in Fig. 6. When the armature of any one of the instruments is set in vibration all the other instruments upon the circuit which are in unison with it respond, but those which have normally a different rate of vibration remain silent. Thus, if A, Fig. 6, is set in vibration, the armatures of A^1 and A^2 will vibrate also, but all the others on the circuit will remain still. So if B^1 is caused to emit its musical note the instruments B B^2 respond. They continue sounding so long as the mechanical vibration of B^1 is continued, but become silent with the cessation of its motion. The duration of the sound may be used to indicate the dot or dash of the Morse alphabet, and thus a telegraphic despatch may be indicated by alternately interrupting and renewing the sound. When two or more instruments of different pitch are simultaneously caused to vibrate, all the instruments of corresponding pitches upon the circuit are set in vibration, each responding to that one only of the transmitting instruments with which it is in unison. Thus the signals of A, Fig. 6, are repeated by A^1 and A^2 , but by no other instrument upon the circuit; the signals of B^3 by B and B^1 ; and the signals of C^1 by C and C^2 — whether A, B^2 , and C^1 are successively or simultaneously caused to vibrate. Hence by these instruments two or more telegraphic signals or messages may be sent simultaneously over the same circuit without interfering with one another.

I desire here to remark that there are many other uses to which these instruments may be put, such as the simultaneous transmission

of musical notes, differing in loudness as well as in pitch, and the telegraphic transmission of noises or sounds of any kind.

When the armature *c*, Fig. 5, is set in vibration the armature *h* responds not only in pitch, but in loudness. Thus, when *c* vibrates with little amplitude, a very soft musical note proceeds from *h*; and when *c* vibrates forcibly the amplitude of the vibration of *h* is considerably increased, and the resulting sound becomes louder. So, if *A* and *B*, Fig. 6, are sounded simultaneously (*A* loudly and *B* softly), the instruments *A*¹ and *A*² repeat loudly the signals of *A*, and *B*¹ *B*² repeat softly those of *B*.

One of the ways in which the armature *c*, Fig. 5, may be set in vibration has been stated above to be by wind. Another mode is shown in Fig. 7, whereby motion can be imparted to the armature by the human voice or by means of a musical instrument.

The armature *c*, Fig. 7, is fastened loosely by one extremity to the uncovered leg *d* of the electro-magnet *b*, and its other extremity is attached to the centre of a stretched membrane, *a*. A cone, *A*, is used to converge sound-vibrations upon the membrane. When a sound is uttered in the cone the membrane *a* is set in vibration, the armature *c* is forced to partake of the motion, and thus electrical undulations are created upon the circuit *E b e f g*. These undulations are similar in sound to the air vibrations caused by the sound — that is, they are represented graphically by similar curves. The undulatory current passing through the electro-magnet *f* influences its armature *h* to copy the motion of the armature *c*. A similar sound to that uttered into *A* is then heard to proceed from *L*.

In this specification the three words "oscillation," "vibration," and "undulation," are used synonymously, and in contradistinction to the terms "intermittent" and "pulsatory." By the term "body capable of inductive action," I mean a body which, when in motion, produces dynamical electricity. I include in the category of bodies capable of inductive action — brass, copper, and other metals, as well as iron and steel.

Having described my invention, what I claim, and desire to secure by Letters Patent, is as follows:

1. A system of telegraphy in which the receiver is set in vibra-

tion by the employment of undulatory currents of electricity, substantially as set forth.

2. The combination, substantially as set forth, of a permanent magnet or other body capable of inductive action, with a closed circuit, so that the vibration of the one shall occasion electrical undulations in the other, or in itself, and this I claim, whether the permanent magnet be set in vibration in the neighborhood of the conducting-wire forming the circuit, or whether the conducting-wire be set in vibration in the neighborhood of the permanent magnet, or whether the conducting wire and the permanent magnet both simultaneously be set in vibration in each other's neighborhood.

3. The method of producing undulations in a continuous voltaic current by the vibration or motion of bodies capable of inductive action, or by the vibration or motion of the conducting-wire itself, in the neighborhood of such bodies, as set forth.

4. The method of producing undulations in a continuous voltaic circuit by gradually increasing and diminishing the resistance of the circuit, or by gradually increasing and diminishing the power of the battery, as set forth.

5. The method of, and apparatus for, transmitting vocal or other sounds telegraphically, as herein described, by causing electrical undulations, similar in form to the vibrations of the air accompanying the said vocal or other sounds, substantially as set forth.

In testimony whereof I have hereunto signed my name this 20th day of January, A.D. 1876.

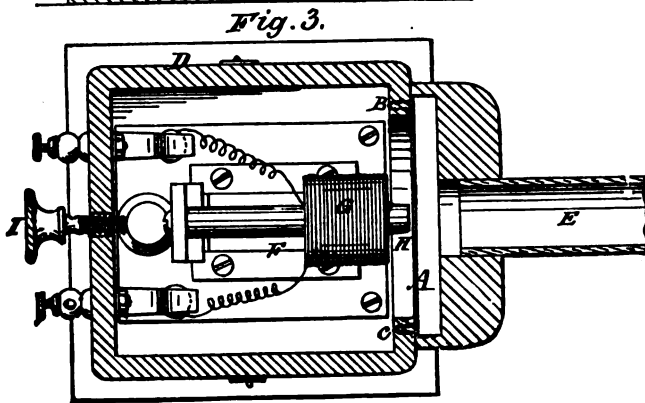
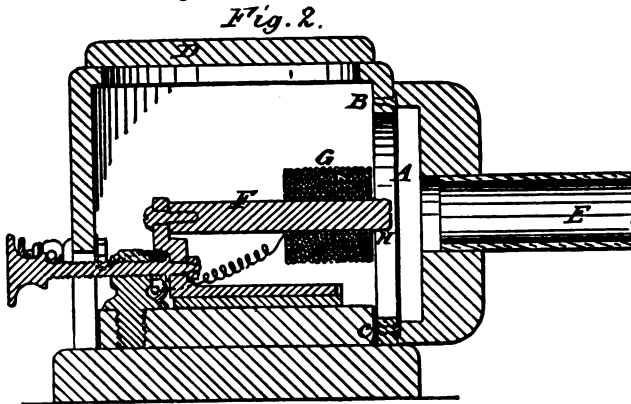
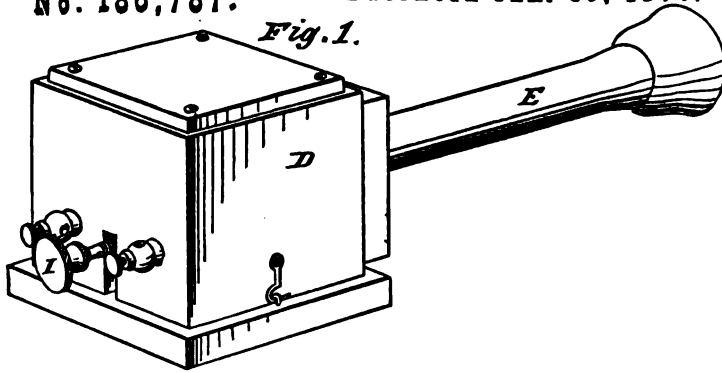
ALEX. GRAHAM BELL.

Witnesses :

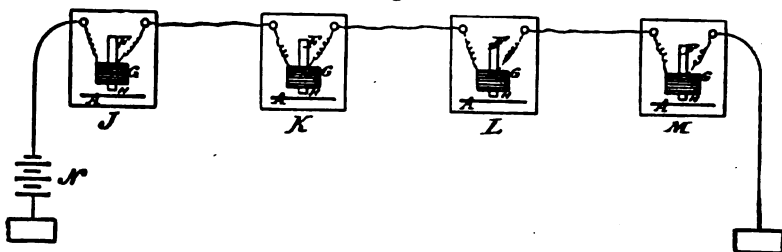
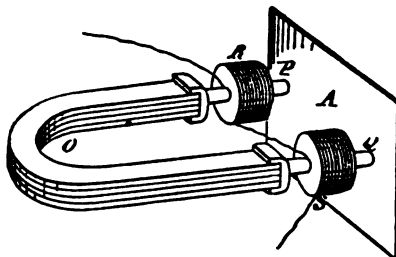
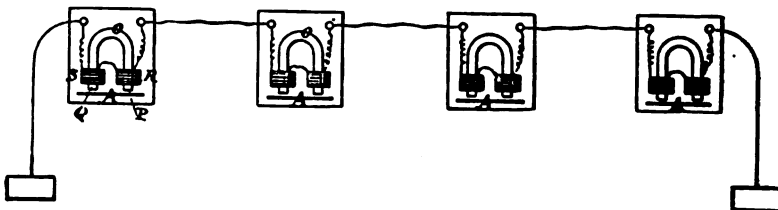
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ELECTRIC TELEGRAPHY.
No. 186,787. Patented Jan. 30, 1877.



A. G. BELL.
ELECTRIC TELEGRAPHY.
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Fig. 4.*Fig. 5.**Fig. 6.*

UNITED STATES PATENT OFFICE.

ALEXANDER GRAHAM BELL, OF BOSTON, MASSACHUSETTS.

IMPROVEMENT IN ELECTRIC TELEGRAPHY.

Specification forming part of Letters Patent No. 186,787, dated January 30, 1877;
application filed January 15, 1877.

To all whom it may concern :

Be it known that I, ALEXANDER GRAHAM BELL, of Boston, Massachusetts, have invented certain new and useful Improvements in Electric Telephony, of which the following is a specification :

In Letters Patent granted to me on the 6th day of April, 1875, No. 161,739, and in an application for Letters Patent of the United States now pending, I have described a method of and apparatus for producing musical tones by the action of a rapidly-interrupted electrical current, whereby a number of telegraphic signals can be sent simultaneously along a single circuit.

In another application for Letters Patent now pending in the United States Patent Office I have described a method of and apparatus for inducing an intermittent current of electricity upon a line-wire, whereby musical tones can be produced and a number of telegraphic signals be sent simultaneously over the same circuit, in either or in both directions; and in Letters Patent granted to me March 7, 1876, No. 174,465, I have shown and described a method of and apparatus for producing musical tones by the action of undulatory currents of electricity, whereby a number of telegraphic signals can be sent simultaneously over the same circuit, in either or in both directions, and a single battery be used for the whole circuit.

In the applications and patents above referred to, signals are transmitted simultaneously along a single wire by the employment of transmitting-instruments, each of which occasions a succession of electrical impulses differing in rate from the others, and are received without confusion by means of receiving-instruments, each tuned to

a pitch at which it will be put in vibration to produce its fundamental note by one only of the transmitting-instruments. A separate instrument is therefore employed for every pitch, each instrument being capable of transmitting or receiving but a single note, and thus as many separate instruments are required as there are messages or musical notes to be transmitted.

My invention has for its object, first, the transmission simultaneously of two or more musical notes or telegraphic signals along a single wire in either or both directions, and with a single battery for the whole circuit, without the use of as many instruments as there are musical notes or telegraphic signals to be transmitted; second, the electrical transmission by the same means of articulate speech and sound of every kind, whether musical or not; third, the electrical transmission of musical tones, articulate speech, or sounds of every kind, without the necessity of using a voltaic battery.

In my Patent No. 174,465, dated March 7, 1876, I have shown as one form of transmitting-instrument a stretched membrane, to which the armature of an electro-magnet is attached, whereby motion can be imparted to the armature by the human voice, or by means of a musical instrument, or by sounds produced in any way.

In accordance with my present invention I substitute for the membrane and armature shown in the transmitting and receiving instruments alluded to above, a plate of iron or steel capable of being thrown into vibration by sounds made in its neighborhood.

The nature of my invention and the manner in which the same is or may be carried into effect will be understood by reference to the accompanying drawings, in which —

Figure 1 is a perspective view of one form of my electric telephone. Fig. 2 is a vertical section of the same, and Fig. 3 is a plan view of the apparatus. Fig. 4 is a diagram illustrating the arrangement upon circuit.

Similar letters in the drawings represent corresponding portions of the apparatus.

A in said drawings represents a plate of iron or steel, which is fastened at B and C to the cover or sounding-box D. E represents a speaking-tube, by which sounds may be conveyed to or from the

plate A. F is a bar of soft iron. G is a coil of insulated copper wire, placed around the extremity of the end H of the bar F. I is an adjusting-screw, whereby the distance of the end H from the plate A may be regulated.

The electric telephones J, K, L, and M are placed at different stations upon a line, and are arranged upon circuit with a battery, N, as shown in diagram, Fig. 4.

I have shown the apparatus in one of its simplest forms, it being well understood that the same may be varied in arrangement, combination, general construction, and form, as well as material of which the several parts are composed.

The operation and use of this instrument are as follows :

I would premise by saying that this instrument is and may be used both as a transmitter and as a receiver — that is to say, the sender of the message will use an instrument in every particular identical in construction and operation with that employed by the receiver, so that the same instrument can be used alternately as a receiver and a transmitter.

In order to transmit a telegraphic message by means of these instruments, it is only necessary for the operator at a telephone (say J) to make a musical sound in any way in the neighborhood of the plate A — for convenience of operation, through the speaking-tube E — and to let the duration of the sound signify the dot or dash of the Morse alphabet, and for the operator who receives his message (say at M) to listen to his telephone, preferably through the speaking-tube E. When two or more musical signals are being transmitted over the same circuit all the telephones reproduce the signals for all the messages ; but as the signals for each message differ in pitch from those for the other messages, it is easy for an operator to fix his attention upon one message and ignore the other.

When a large number of despatches are being simultaneously transmitted it will be advisable for the operator to listen to his telephone through a resonator, which will re-enforce to his ear the signals which he desires to observe. In this way he is enabled to direct his attention to the signals for any given message without being distracted or disturbed by the signals for any other messages that may be passing over the line at the time.

The musical signals, if preferred, can be automatically received by means of a resonator, one end of which is closed by a membrane, which vibrates only when the note with which the resonator is in unison is emitted by the receiving-telephone. The vibrations of the membrane may be made to operate a circuit-breaker, which will actuate a Morse sounder or a telegraphic recording or registering apparatus.

One form of vibratory circuit-breaker which may be used for this purpose I have described in Letters Patent No. 178,399, June 6, 1876. Hence by this plan the simultaneous transmission of a number of telegraphic messages over a single circuit in the same or in both directions with a single main battery for the whole circuit and a single telephone at each station is rendered practicable. This is of great advantage in this, that for the conveyance of several messages, or signals, or sounds over a single wire simultaneously, it is no longer necessary to have separate instruments correspondingly tuned for each given sound, which plan requires nice adjustment of the corresponding instruments, while the present improvement admits of a single instrument at each station, or, if for convenience several are employed, they all are alike in construction, and need not be adjusted or tuned to particular pitches.

Whatever sound is made in the neighborhood of any telephone — say at J, Fig. 4 — is echoed in fac-simile by the telephones of all the other stations upon the circuit; hence this plan is also adapted for the use of the transmitting intelligibly the exact sounds of articulate speech. To convey an articulate message it is only necessary for an operator to speak in the neighborhood of his telephone, preferably through the tube E, and for another operator at a distant station upon the same circuit to listen to the telephone at that station. If two persons speak simultaneously in the neighborhood of the same or different telephones, the utterances of the two speakers are reproduced simultaneously by all the other telephones on the same circuit; hence by this plan a number of vocal messages may be transmitted simultaneously on the same circuit, in either or both directions. All the effects noted above may be produced by the same instruments without a battery by rendering the central bar F H permanently magnetic. Another form of telephone for use without

a battery is shown in Fig. 5, in which O is a compound permanent magnet, to the poles of which are affixed pole-pieces of soft iron, P Q, surrounded by helices of insulated wire R S.

Fig. 6 illustrates the arrangement upon circuits of similar instruments to that shown in Fig. 5.

In lieu of the plate A in above figures, iron or steel reeds of definite pitch may be placed in front of the electro-magnet O, and, in connection with a series of such instruments of different pitches, an arrangement upon circuit may be employed similar to that shown in my patent No. 174,465, and illustrated in Fig. 6 of Sheet 2 in said patent. The battery, of course, may be omitted.

This invention is not limited to the use of iron or steel, but includes within its scope any material capable of inductive action.

The essential feature of the invention consists in the armature of the receiving-instrument being vibrated by the varying attraction of the electro-magnet so as to vibrate the air in the vicinity thereof in the same manner as the air is vibrated at the other end by the production of the sound. It is, therefore, by no means necessary or essential that the transmitting-instrument should be of the same construction as the receiving-instrument. Any instrument receiving and transmitting the impression of agitated air may be used as the transmitter, although, for convenience and for reciprocal communication, I prefer to use like instruments at either end of an electrical wire. I have heretofore described and exhibited such other means of transmitting sound, as will be seen by reference to the proceedings of the American Academy of Arts and Sciences, Volume XII.

For convenience, I prefer to apply to each instrument a call-bell. This may be arranged so as to ring, first, when the main circuit is opened; second, when the bar F comes into contact with the plate A. The first is done to call attention; the second indicates when it is necessary to readjust the magnet, for it is important that the distance of the magnet from the plate should be as little as possible, without, however, being in contact. I have also found that the electrical undulations produced upon the main line by the vibration of the plate A are intensified by placing the coil G at the end of the bar F nearest the plate A, and not extend it beyond the middle, or thereabout.

Having thus described my invention, what I claim and desire to secure by Letters Patent, is —

1. The union upon, and by means of, an electric circuit of two or more instruments, constructed for operation substantially as herein shown and described, so that, if motion of any kind or form be produced in any way in the armature of any one of the said instruments, the armatures of all the other instruments upon the same circuit will be moved in like manner and form, and if such motion be produced in the former by sound, like sound will be produced by the motion of the latter.

2. In a system of electric telegraphy or telephony, consisting of transmitting and receiving instruments united upon an electric circuit, the production, in the armature of each receiving-instrument, of any given motion by subjecting said armature to an attraction varying in intensity, however such variation may be produced in the magnet; and hence I claim the production of any given sound or sounds from the armature of the receiving-instrument by subjecting said armature to an attraction varying in intensity, in such manner as to throw the armature into that form of vibration that characterizes the given sound or sounds.

3. The combination, with an electro-magnet, of a plate of iron or steel, or other material capable of inductive action, which can be thrown into vibration by the movement of surrounding air or by the attraction of a magnet.

4. In combination with a plate and electro-magnet, as before claimed, the means herein described, or their mechanical equivalents, of adjusting the relative position of the two so that, without touching, they may be set as closely together as possible.

5. The formation, in an electric telephone such as herein shown and described, of a magnet with a coil upon the end or ends of the magnet nearest the plate.

6. The combination, with an electric telephone such as described, of a sounding-box, substantially as herein shown and set forth.

7. In combination with an electric telephone, as herein described, the employment of a speaking or hearing tube for conveying sounds to or from the telephone, substantially as set forth.

8. In a system of electric telephony, the combination of a per-

manent magnet with a plate of iron or steel, or other material capable of inductive action, with coils upon the end or ends of said magnet nearest the plate, substantially as set forth.

In testimony whereof I have hereunto signed my name this 13th day of January, A.D. 1877.

A. GRAHAM BELL.

Witnesses :

HENRY R. ELLIOTT.

EWELL A. DICK.

THE UNIVERSITY OF MICHIGAN

DATE DUE

