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## HOW BELL INVENTED THE TELEPHONE

BY THOMAS A. WATSON

**I**T IS my privilege and pleasure to speak to you of the invention of the telephone, with which event it was my good fortune to be connected, my association with Prof. Bell as his mechanical expert having brought me into close touch with nearly all his experiments both before and after his great discovery.

I shall try to tell the story as it impressed itself on my mind in those early days when I was a young man of about 20, just out of my apprenticeship as a maker of electrical apparatus, intensely interested in my work, and with a full share of youthful enthusiasm. In my story, I shall not use the terms and formulas of modern telephony, for they would certainly be out of place in speaking of the time when that science, now so complex, was contained in one human brain.

It was in the year 1875 that the telephone emerged from the mists of the unknown into a world that had no dynamos, no electric motors, no trolley cars, no storage batteries, no electric lights, no wireless telegraphs, no steam turbines, no gas engines, no automobiles, and no professional electrical engineers, for none of our universities had up to that time offered to their students electrical courses.

Those men we all revere—Davy, Faraday, Henry, Volta, Oersted, Ohm, Maxwell, Thomson, and others, had already laid the deep and sure foundations on which modern electrical practise has been built, but apart from the telegraph, electricity, as a practical utility, had scarcely entered the daily life of man.

In 1874 in place of the great electrical manufacturing establishments of the present day, there were a few crude little work shops scattered throughout the country, eking out a precarious existence chiefly by making telegraph instruments, school apparatus, call bells, annunciators, etc., and also experimental apparatus for the many inventors who utilized the meagre facilities of those shops to put into practical shape

their electrical projects. This was an important feature of the electrical activities of that time, for although the work of these men was for the most part obscure and unfruitful, they were undoubtedly the leaders in the great awakening to the practical possibilities of electricity that began about the time of which I am to speak, and which has since then produced such tremendous results.

In 1874 I was employed as a mechanic in one of the most important of these shops in the United States. It was in Boston, owned and operated by Charles Williams, trained as an apprentice of that famous electric antique, Daniel Davis. Williams, when he was very busy, employed about fifty men, but while I was with him his works seldom ran at more than fifty per cent of their normal capacity. His tools were almost entirely hand lathes. His shop possessed no milling nor screw machine nor had it even a metal planer. Practically all his work was done on hand lathes or with the vise and file. He had one 16-inch engine lathe, to operate which was the highest earthly aspiration of his apprentices. It wasn't in good condition, for one of the boys had run a boring tool into the hole in the spindle so the live center wiggled badly, but we managed to do some rather difficult and accurate work on it in spite of its defects.

Into Williams's dismal and poorly equipped shop Alexander Graham Bell came, in the year 1874, to get his "harmonic telegraph" invention put into practical shape. J. B. Stearns had just then perfected the "duplex telegraph" which would send two messages simultaneously over a single wire. Prof. Bell was sure his invention would send at least six or eight. My work at Williams's at that time had become largely making experimental apparatus for inventors and I am glad to say that Prof. Bell's work was assigned to me.

Prof. Bell was very enthusiastic over the possibilities of his telegraph on which he had been studying ever since his arrival in the United States in 1872. Its operation depended, as you know, on the fact that a stretched string or a tuned reed will be set into vibration when impelled by a succession of impulses corresponding in number per second to its pitch. Here is one of Bell's telegraph receivers. It is a simple electromagnet with a strip of steel clamped to one of its poles, having the other end of the strip free to vibrate over the other pole. The transmitter had the same parts with the addition of contact

points that kept its steel reed vibrating when the current was connected and, making and breaking the main circuit at each swing, sent an intermittent current pulsing into the line and through the distant receivers. Each receiver reed was expected to respond to impulses of its own pitch and to ignore those of any other pitch.

I made for Prof. Bell six or eight of these transmitters with their reeds tuned to different pitches and the same number of receivers with their reeds tuned to correspond. Their test, however, gave results sadly out of accord with his expectations and a long series of experiments followed with rather unsatisfactory results.

The saying so frequently offered for our consolation: that we profit more from our adversities than we do from our successes, was certainly applicable to Prof. Bell's case at this time, for had the rhythmic intermittent current that actuated his telegraph accomplished the result he expected and brought him fame and fortune, he might not have been impelled to seek a better form of an electric vibration and so might have missed the discovery that has since placed his name among the immortals.

Prof. Bell's experiments with the apparatus I made for him soon revealed the serious defects of the intermittent current wave. He was able to transmit with it two or three messages, each on a different pitch, with a reasonable degree of certainty, but when a greater number was attempted, the added series of impulses seemed to fill the gaps in the other series and produce practically a continuous current, causing serious interference between the messages. The need of a better form of an electric wave was apparent; making and breaking the circuit so many times a second seemed but the first step in the development of his idea. The fact is, Bell had had for a year or more a clear conception of the sort of current he needed, one undulating in waves which would be the exact equivalent of sound vibrations, although he had as yet devised no satisfactory means of producing such a current. An electric current undulating in true wave form would not, he believed, smooth out into a continuous current when several series of impulses were superposed but would keep its wave form through all the complexities that might be impressed upon it. Many sounds can traverse the same air without confusion, so, he thought, such a system of electric waves having the mathe-

matal form of sound waves in the air, might transmit an indefinite number of pitch series on a single wire, to be selected and resolved into separate messages by his tuned receivers.

Bell also foresaw that the apparatus which could generate and transmit such true electric waves might also solve another great problem he had been dreaming about.

One must imagine a world in which the telephone was absolutely unknown to appreciate my feelings when one evening during the course of some experiments on his telegraph apparatus, Bell told me he had an idea by which he believed it would soon be possible to talk by telegraph. He put his conception into the words of his famous formula which I then heard for the first time: "If," he said, "I could make a current of electricity vary in its intensity, precisely as the air varies in density during the production of a sound, I should be able to transmit speech telegraphically." Some practical mechanism to produce such a current was the goal to be striven for, he asserted. He then described to me what he called his "harp telephone," a complex affair having an elongated electromagnet with a multiplicity of steel reeds tuned to many pitches and arranged to vibrate in proximity to its poles; as if the magnets of a hundred of these receivers were fused together side by side. These reeds might be considered as analagous to the rods in the harp of Corti in the human ear. It was Bell's first conception of a speaking telephone. His idea was that a sound uttered near the reeds would cause to vibrate those reeds corresponding to both the fundamental tone and to the overtones of that sound. Each reed would generate in the magnet an electric wave all of which would combine into a resultant complex wave. This passing through a similar instrument at a distant station would, he imagined, set the same reeds into motion and so reproduce the original sound. He had even considered the possibility of using a single reed actuated by a parchment diaphragm over an ordinary electromagnet. He had not had either of his conceptions constructed for he was sure that electric waves generated in this way would be too feeble, to be of the least practical value. His harp telephone, however, was a favorite idea with him and he often spoke of it to me. It was never constructed probably on account of the expense, but with this clear conception in his mind, of the possibilities of a true electric wave, struggling for practical expression, Bell continued his work on his harmonic telegraph

trying to attain a result clearly impossible with a transmitter that merely made and broke the circuit.

I am afraid that my attitude towards Bell's telegraph, after several months' work on it, had become one of disgust with its perversities, and hopelessness as to its future. Its operation was so uncertain and baffling that I remember that even Prof. Bell himself began to lose his enthusiasm. His confidence in the intermittent current was vanishing and means for generating his better waves had not arrived. But, "when half gods go, the gods arrive," and this time of depression and disappointment was the right preparation for the new development that was close at hand.

In the attic of the building 109 Court street, Boston, where Williams's shop was, two rooms had been partitioned off and used by Williams for the manufacture of tin-foil condensers. These rooms Bell used as his laboratory at that time. Those rough attic rooms, freezing in winter and unbearably hot in summer, had witnessed many discouraging experiments with the harmonic telegraph with a few slight successes, but on the afternoon of June 2d, 1875, something came to light there that certainly was a recompense for all previous troubles. A slight derangement in the telegraph apparatus gave an opportunity for the great idea that had been incubating in Bell's mind so long to break through its shell.

On that afternoon Bell was in one of the rooms tuning the receivers, an operation they constantly needed. He had a novel way of doing this that he had originated and which had become a habit with him. When he was trying to bring the pitch of a receiver reed into accord with that of its transmitter, he would press that receiver reed against his ear. He could then hear the nasal drone of the intermittent current coming from the transmitter in the other room and by changing the length of the receiver reed he could adjust its pitch to correspond with that tone. It is interesting to note that when one of his harmonic receivers is used in this way, it becomes a close analogue of a modern telephone receiver, as the edges of the ear clamp the free end of the spring and so damp its natural rate of vibration and cause it to vibrate as a diaphragm.

On the afternoon of June 2d, 1875, Bell was doing this with one of the receivers and at that very moment I happened to snap the steel reed of another instrument in the other room connected into the same circuit, which for some reason was

not vibrating as it should, and needed that physical stimulus to start it. It did not start at once so I gave it several vigorous plucks, undoubtedly expressing my opinion of the thing in vivid shop language, when I heard a commotion in the next room and out Bell came in great excitement to see what I had been doing, telling me that he had heard in the receiver at his ear the unmistakable timbre of the sound of one of the reeds. His excitement came from his realization that he had heard the first real sound that had ever been transmitted electrically. It needed but a slight examination of the apparatus to reveal the fact that the steel reed I had snapped, magnetized by its long use in connection with magnets, was functioning as a magneto-electric generator and by its vibration had generated in its magnet an electric current that was moulded into undulations exactly analogous to the sound waves of the plucked reed. That such slight means could generate a current not only strong enough to be heard in the receiver but actually to set into visible vibration the reed of another receiver in the same circuit in Bell's room, was a revelation to him. He saw at once that he had been wrong in thinking that the vibration of a steel reed could not produce electric waves of any practical value and that here was the solution, not only of his harmonic telegraph but also of his speaking telephone. He realized immediately that the apparatus that could generate, transmit and receive so efficiently one sound with its fundamental tone and with its overtones could undoubtedly be made to do the same for any sound, even speech itself. The gods had arrived, bringing new enthusiasm and hope; even my gloom was dispelled. We spent the rest of the day repeating the experiment by snapping many different sizes and shapes of steel springs and tuning forks over magnets with the same surprising result and before we parted that night Bell gave me directions for constructing the first speaking telephone. He knew that the diaphragm of the Scott phonautograph when impelled by the vibrations of sound would impress them on the recording style attached to it; why then would not such a diaphragm actuated by the voice, force the steel reed of one of his receivers to follow the vocal vibrations and cause it to generate electric waves with the form of speech waves? Following this thought to its conclusion, Bell sketched out the first speaking telephone the world has ever seen and gave me directions for its construction. I was to mount one of the harmonic receivers in a wooden

frame, attach the free end of its spring to the center of a tightly stretched parchment drum head, also mounted in the framework, and provide a mouthpiece to concentrate the voice on the other side of the drum head.

I did this the next day. Here is a replica of it. All that is left of the original is now in the National Museum at Washington. My recollection is that I had this first telephone ready for testing the next day, June 3d. It had many defects. The diaphragm was delicate and easily torn and as it absorbed the moisture of the breath required constant tightening, but it transmitted to my ear over a wire about 200 feet long, running from the fifth story of Williams's building to my work bench on the third story, the unmistakable timbre of Prof. Bell's voice in a few imperfect words, using for listening one of the harmonic telegraph receivers through which Bell had made the discovery. It was a meager result and a bitter disappointment, for I, at least, and, I fancy, Prof. Bell too, had anticipated a much greater conversational fluency even in that first telephone.

I have noticed that one's mental attitude towards a phenomenon changes as the novelty wears off. The new effect does not seem so wonderful after a few repetitions. This is perhaps the reason why my memory tells me that during the months immediately following the discovery that magneto-electric waves generated by a vibrating steel reed were strong enough for practical use, the telephone seemed to grow poorer in its operation instead of better. Bell carried on many experiments for which I made the apparatus, with the purpose of increasing the strength of the new wave not only for its use in his telegraph but also in his telephone. He felt that any improvement applicable to one invention would also help the other. His work for some months was devoted to the telegraph as well as to the telephone, for his friends and financial backers were all strongly of the opinion that it was much wiser for him to devote himself to a real practical thing like the telegraph rather than to such a chimera as the telephone.

Progress was over the same desert road with a few green spots that inventions seem prone to travel on and it was not until March 10th, 1876, nearly ten months after its birthday that the telephone transmitted its first complete sentence. Though not so noble as the first sentence that Morse telegraphed from Washington to Baltimore a few decades before, "What hath God wrought," still the telephone's first sentence had a

certain homely practicality about it that clearly takes it out of the category of the frivolous. It was, "Watson, come here, I want you," uttered by Bell from his laboratory to his bed room in the boarding house, number 5, Exeter Place, Boston. I am sure that I went at once. Commonplace as it was, the sentence seemed to break the spell and the telephone progressed after that by leaps and bounds.

I have here the wire over which that first sentence was sent. With a forethought that quite surprises me today, I took down this wire when the laboratory was vacated in 1877, inscribed it and put it into a safe where it remained until a year or two ago when I presented it to the American Telephone and Telegraph Co. for its museum. The inscription, which I wrote when I first took it down, is as follows: "This wire connected room 13 with room 15 at number 5 Exeter Place, Boston, and is the wire that was used in all the experiments by which the telephone was developed from the fall of 1875 to the summer of 1877, at which time the telephone had been perfected for practical use. Taken down June 8th, 1877, by Thomas A. Watson."

This was the year of the Centennial Exposition at Philadelphia and Bell decided to make an exhibit there of his inventions. He had me make for him some nicely finished telephones of the best forms that he had devised, including his first battery transmitter.

In June, 1876, Sir William Thomson, chairman of the committee on the electrical exhibits, with members of his committee, examined and tested Bell's apparatus. We have a valuable record of the impression the telephone made upon his mind in his opening address to the British Association, September 14th, 1876, wherein he said:

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 disk armature of just such another little electromagnet 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 tele-

graph 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 electromagnet 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 Edinburgh, 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?

Up to the summer of 1876 all the tests of the telephone had been made on indoor wires but soon after this convincing trial at Philadelphia, it became evident to Prof. Bell that his invention was ready for higher flights. Some preliminary tests on a real line in Brandford, Canada, in which the transmission was all in one direction, the return communication being by telegraph, were followed by a complete test of the telephone's practicability as a transmitter of intelligence between distant points under outdoor conditions. On October 9th, 1876, Bell and I carried on a long conversation over a real telegraph wire about two miles long running from Boston to Cambridge, Mass. Bell was at the Boston end, I at Cambridge. The telephones we used were those that Bell had exhibited at Philadelphia and were probably the identical instruments with which Sir William Thomson made his famous tests. In order to prove to a doubting world that the telephone could be accurate in its transmission, we made a record of that first conversation ever carried on over a real line and so it has been preserved. At the beginning of the test we were not able to make our voices audible to each other. The cause seemed to be the high resistance of a telegraph relay that I discovered in the circuit in another room in the Cambridge factory, for, after I cut that out, we were able to talk with the greatest ease, as the opening sentences of our recorded conversation indicate, which were:

"Bell: What do you think was the matter with the instruments?

Watson: There was nothing the matter with them.

Bell: I think we were both speaking at the same time.

Watson: Can you understand anything I say?

Bell: Yes, I understand everything you say.

Watson: The reason why you did not hear at first was because there was a relay in the circuit.

Bell: You may be right, but I found the magnet of my telephone touching the membrane.

Watson: I cut this relay out, and then the sounds came perfectly.

Bell: I hear every syllable. Try something in an ordinary conversational voice.

Watson: I am now talking in quite a low tone of voice.

Bell: The sounds are quite as loud as before and twice as distinct"—

and so on for more than a hour. This record which was published in the *Boston Advertiser* of the next day shows a surprising accuracy when the crudeness of those early telephones is taken into consideration.

I need go no further in my account of those days of struggle. The successful working out of the telephone, as in the case with all inventions, was a matter of endlessly considered detail. It was patient, plodding work with a few hours of intense excitement. Other tests were made later in 1876 on still longer lines, and in April, 1877, the first telephone line was constructed, four miles long, and the telephone installed thereon, beginning its competition with the telegraph as a practical business proposition.

Since then, what tremendous things have been done by the telephone engineers on whom the responsibility has fallen, of continuing the work so splendidly inaugurated by Dr. Bell. The work of these men during the 38 years that has elapsed since Dr. Bell's experiments on the telephone has been ceaseless, energetic, untiring, wise, and accurate in the highest degree. Telephone engineers have overcome one by one the multitude of obstacles that stood in the way of that high ideal—universal service, until today we applaud the latest achievement, under the able leadership of your incoming president—transcontinental telephony, the marvel of which has impressed itself deeply upon my mind all the more because Dr. Bell and I had the honor of formally opening the New York-San Francisco telephone line on January 25th of this year, as we opened the first telephone line, 2 miles long, between Boston and Cambridge, 39 years before. We talked over this line 3400 miles long (really 4400 miles, for its terminus was, during the most of the time, in Jekyll Island, Georgia) more clearly than we talked from Boston to Cambridge 39 years before. Amazing

as this was, a climax of the wonders I had been participating in was reached when Dr. Bell switched in another telephone and said to me through it: "Mr. Watson, I am now talking through an exact duplicate of the first telephone made in 1875. Can you hear me?" I heard him perfectly, and when I explained to the audience at my end of the line just what was happening and repeated Dr. Bell's words, I was not surprised to see tears in the eyes of several of those hard-headed business men of California, for I myself was thrilled through and through with the thought of the immensity of the work that had been done since I made that first telephone for Prof. Bell and with my realization that this transcontinental line, stupendous achievement as it is, was merely a big incident in the life of the men whose brains have built up an organization almost incomprehensible in its size and scope, with its nine million telephone stations, making twenty-eight million telephone conversations each day over twenty million miles of telephone wires—that stupendous organization we call the "Bell system."

Even these figures are but part of the whole, for there are now in the world more than 14 million telephone stations, making 42 million conversations daily over 33 million miles of wire. We can but wonder at such a fructification in four decades of that virile conception of the man we today honor ourselves by honoring—Alexander Graham Bell.

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