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THE GRAMOPHONE: ETCHING THE HUMAN VOICE.

BY EMILE B RLINER.

[*A paper read at the Stated Meeting of the* FRANKLIN INSTITUTE, *May 16, 1888.*]

JOS. M. WILSON, President, in the chair.

THE PRESIDENT introduced Mr. BRELINER, who spoke as follows:

MEMBERS OF THE FRANKLIN INSTITUTE, LADIES AND GENTLEMEN:—The last year in the first century of the history of the United States was a remarkable one in the history of science.

There appeared about that period something in the drift of scientific discussions, which, even to the mind of an observant amateur, foretold the coming of important events.

The dispute of Religion *versus* Science was once more at its height; prominent daily papers commenced to issue weekly discussions on scientific topics; series of scientific books in attractive popular form were eagerly bought by the cultured classes; popular lectures on scientific subjects were sure of commanding

enthusiastic audiences; the great works on evolution had just commenced to take root outside of the small circle of logical minds from which they had emanated, and which had fostered them. Scientific periodicals were expectantly scanned for new information, and the minds of both professionals and amateurs were on the *qui vive*.

Add to this the general excitement prevailing on account of the forthcoming centennial celebration with its crowning event, so dear to this nation of inventors, the world's exhibition, and even those who did not at the time experience the effects of an atmosphere pregnant with scientific ozone, can, in their minds, conjure up the pulsating, swaying, and turbulent sea of scientific research of that period. Science evidently was in labor.

The year 1876 came, and when the jubilee was at its very height, and when this great City of Philadelphia was one surging mass of patriots filling the air with the sounds of millions of shouts, a still small voice, hardly audible, and coming from a little disk of iron fastened to the centre of a membrane, whispered into the ear of one of the judges at the exhibition, and one of the greatest of living scientists, the tidings that a new revelation had descended upon mankind, and that the winged and fiery messenger of heaven's clouds had been harnessed to that delicate, tremorous, and yet so potent form of energy, called the Human Voice.

The speaking telephone had been born.

The stimulus which this event gave to science can best be measured by the enormous advance made since, especially in that now most prominent branch, electricity, and I will show further on how, immediately following it, our sister republic across the ocean answered the magic touch by the conception of another invention, the scope of which cannot to-day be measured yet and which only just now is starting on its career of usefulness among the practical arts.

In order to show the influence which these two inventions had upon each other, and how their respective development came about in parallel steps, permit me, before entering upon the new methods which I am to bring before you to-night, to pass in rapid review on the principal events in the history of the

transmission of speech electrically, and of recording and reproducing the same mechanically.

In 1854, Charles Bourseuil, with more than usual boldness, advanced the idea that two diaphragms, one operating an electric contact, and the other under the influence of an electro-magnet, might be employed for transmitting speech over telegraphic distances. "Speak against one diaphragm," he said, "and let each vibration break or make the electric contact, and the electric pulsations thereby produced will set the other diaphragm vibrating, and the latter ought then to reproduce the transmitted sound." Outside of the fallacy which his theory contained in the assumption of breaking the contact, instead of merely modifying the same, Bourseuil's paper, in speaking of the diaphragm, laid stress upon stating that "if one could be invented so movable and flexible as to answer to all the undulations of sound." He evidently desired extreme flexibility, and diaphragms constructed on that principle proved fatal to the efforts of many subsequent experimenters; even at first to Mr. Bell, who, like Bourseuil, borrowed the idea from the flexible *tympanum membrani* of the human ear, and who overlooked the important modifications which the vibrations undergo, before reaching the auditory nerve, by the series of muscular hinges in which the various bony accessories of the ear are mounted, and which act as elastic dampers against the *tympanum membrani.*

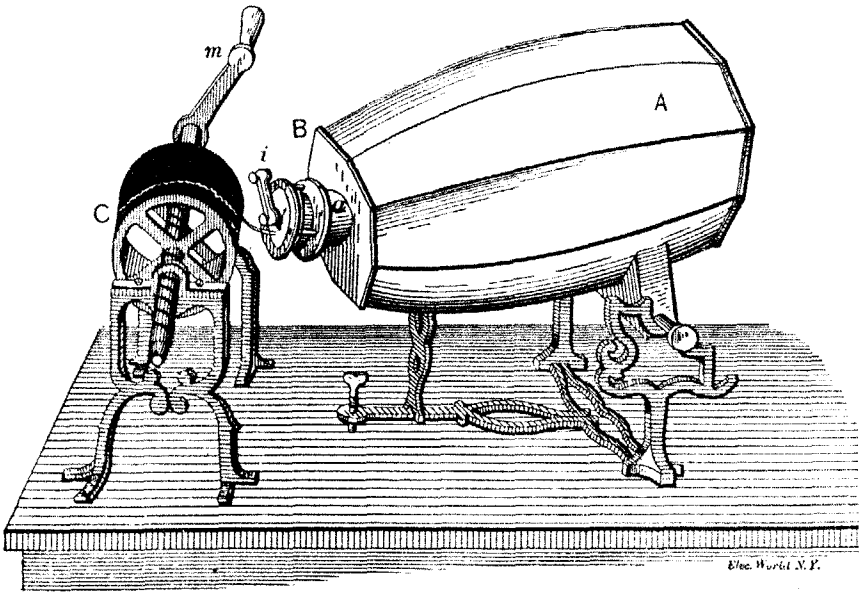
Bourseuil's ideas were immediately reprinted from French journals in other countries, and among the first was a prominent German semi-weekly journal, printed in Frankfurt-on-the-Main, *The Didaskalia*, which, on September 28, 1854, under the heading "Electrical Telephony," published a leading article, giving a full account of Bourseuil's ingenious and wonderful conception.

Frankfurt was then a city of about 60,000 inhabitants, and among other institutes of learning, it supported a Physical Society, which counted, at the time of this publication, among its active and most zealous members, an enthusiastic young teacher named Philip Reis, who, five years afterward, actually made an apparatus such as indicated by Bourseuil (who had since died without executing his idea), and which apparatus has since become known as the Reis telephone.

I will not now enter upon any controversy as to the scope of

this invention, regarding the possibility at the present day to transmit speech with the same. It may suffice to state that, when the news of the Bell telephone reached the learned men of Germany, some of the very first scientists in Berlin who knew all about the Reis apparatus, doubted the possibility of the performance as represented by the American press. It is also now a matter of history, that in the late decision in favor of Mr. Bell, the United States Supreme Court was unanimous so far as the Bourseuil-Reis apparatus was concerned.

FIG. 1.



Scott's Phonautograph.

While Bourseuil's conception was being digested by Reis, another invention, having also a membrane diaphragm as its motive principle, was patented in France in 1857. This was the phonautograph, by Léon Scott, which had for its purpose the recording of sound vibrations upon a cylinder rotated by hand and moved forward by a screw (Fig. 1). The cylinder was covered with paper, this was smoked over a flame, and a stylus attached to the centre of a diaphragm under the influence of words spoken into a large barrel-like mouthpiece, would trace sound vibrations

upon the smoky surface. Scott also employed an animal membrane for his diaphragm, and took pains, by means of an attachment called a sub-divider, to make the vibrations appear as large as possible. This sub-divider, however, became the prototype of the dampers in subsequent apparatus, like the Blake transmitter and the Edison phonograph.

The next important event in electro-phonic and acoustic science was the publication by Helmholtz of his investigations in sound, and of König in the same line of research, but classical as these publications will forever remain, they for a time retarded the progress of apparatus for practical use, for the reason that they discouraged inventors by the mechanical complications which they apparently ascribed as indispensable to articulate speech. In fact, the perusal of their work left a serious doubt in the mind of many a student, whether there was not something in articulate speech and its audibility by the human ear, beyond the grasp of the mechanical mind of man.

These doubts were still increased by the attempts of Faber to construct a talking machine, after the system of the human organs of speech, a mass of intricate mechanism, levers, bellows, and pulleys, which gave an unearthly rendition of many words and sentences.

But the Bell telephone came, and its greatness consisted not so much in the fact that it carried speech over hundreds of miles, but that it taught how simple a piece of apparatus could produce such perfect results, and that any diaphragm however thick, could be made to set up audible articulate vibrations.

The effect of this lesson was immediate, for hardly had the new wonder become known when an astonishing chain of logic formed in the brain of a distant devotee to science.

On the 30th day of April, 1877, Mr. Charles Cros deposited with the Secretary of the Academy of Sciences in Paris a sealed envelope, containing what in translation reads as follows:

"Process of Recording and of Reproducing Audible Phenomena."

"In general, my process consists in obtaining the tracing of the to-and-fro movements of a vibrating membrane, and the utili-

zation of this tracing for reproducing the same to-and-fro movements, with their relative inherent durations and intensities in the same membrane, or in another adapted for furnishing the sounds and noises which result from this series of movements.

"We are, therefore, concerned with the transformation of an extremely delicate tracing, such as that obtained with a delicate stylus rubbing upon a surface blackened by a flame, to transform, I say, these tracings in relief or intaglio, in resisting material capable of guiding a moving body, which transmits these movements to the sonorous membrane.

"A light stylus is connected with the centre of a vibrating membrane; it terminates in a point (metallic wire, the barb of a feather, etc.), which bears upon a surface blackened by a flame. This surface is a part of a disk to which is given a double movement of rotation and rectilinear progression.

"If the membrane is at rest, the point will trace a simple spiral; if the membrane vibrates, the traced spiral will be undulating, and these undulations represent exactly all the to-and-fro movements of the membrane, with their times and intensities."

Up to this point the apparatus as described would represent a modified Scott phonautograph, in which the cylinder is substituted by a flat disk. Mr. Cros then continues:

"By means of the photographic process which, in fact, is well known, this traced, transparent, undulatory spiral is converted into a line of similar dimensions, in intaglio or in relief, in resisting material like tempered steel, for instance.

"This done, this resisting surface is, by means of a motor apparatus, made to turn and to progress rectilinearly with a velocity like that which was used in the registration.

"If the reproduced tracing is in intaglio, a metallic point (and if it is in relief, a notched finger), held by a spring, bears upon the tracing at one end and is connected at the other end with the centre of the membrane adapted for sound reproduction. Under these conditions, this membrane is not any more acted upon by the vibrating air, but by the tracing controlling the pointed stylus by pulsations exactly like those to which the membrane was subjected in recording, both as to duration and intensity.

"The spiral trace represents the successive equal periods by its increasing and decreasing length. There is nothing inconve-

nient in this if only the outer portion of the rotating circle is used, and if the spirals are close together, except that the central part of the disk is lost.

"In all cases, however, a helical tracing upon a cylinder is much to be preferred, and I am actually engaged in finding a practical embodiment of this."

This paper was only read in open session at the Academy on December 3, 1877, and in the meantime Mr. T. A. Edison appeared with the phonograph.

From what we can learn by published reports, Mr. Edison, some time in the latter part of September in the same year, was at work on an automatic telephone, by which he intended to impress a telephone message upon a strip of tin-foil, and let the indentations thereby produced act upon a variable resistance, such as a lampblack button, and thereby transmit the message over the wire. While one day at work on this, so the report runs, he, perchance, slipped the previously indented slip under the recording stylus which, as in the Scott phonautograph, was connected to the centre of a diaphragm, and then and there occurred the first actual reproduction by mechanical means of words registered before.

The phonograph became then, at once, an accomplished fact, for to such an experienced inventor it must have taken but a moment to mentally cover the cylinder of a Scott phonautograph with tin-foil and to indent the same at right angles to the surface of the cylinder.

Everybody remembers the sensation which the invention produced, and the prognostications which were advanced for it by the scientific press showed that the principle of the apparatus was considered to contain the germ of an ultimate achievement of the most accurate results.

In this respect, as well as in others, there are striking resemblances in the history of the two inventions with which I am dealing.

In both, the original idea emanated from Frenchmen, and both described one process of transmitting, and a different process of reproducing speech. In the Bourseuil telephone there was a contact transmitter and an eloctro-magnet receiver; in the Cros

phonograph, a written record and an engraved reproducing groove.

In both inventions the first realization occurred in the United States, and was effected with apparatus representing only the reproducer of the original conception. In the speaking telephone, the reproducing electro-magnet of Bourseuil became also the transmitter of Bell, and in the phonograph, the reproducing groove and stylus of Cros became also the record of Edison. Both the Bell and Edison apparatus were accepted for a time as containing the best mechanical and philosophical principle for the highest attainable results. In both, the aim at the beginning was to produce loud sounds, and both eventually contented themselves with a much fainter voice, which then became more distinct in articulation. Finally, in both inventions, the original transmitter was subsequently resurrected, and found to contain a pointer toward a superior principle as a transmitter and recorder, and it only remains now to use a Scott phonautographic record direct for reproduction in order to complete a parallel with the fact that a contact transmitter can also be used as a telephonic reproducer.

In making these parallels, however, I am aware of the fact that Cros had a better idea of a talking machine than Bourseuil had of a speaking telephone.

The paper of Mr. Cros, which can be found on page 1082, vol. 85, of the *Comptes Rendus* of 1877, appears to have been consigned immediately to obscurity. When ten years later, I filed my patent application for the gramophone, not even the Examiners at the Patent Office knew anything of Mr. Cros, and when I mentioned his name in the first publication of the "gramophone," even those best informed on the subject were surprised. Nevertheless, I considered it a duty to my friends to make the following statement to the Editors of *The Electrical World*, which they published simultaneously with the "gramophone," on November 12, 1887. I said:

"On August 30, of this year, which was three months after the filing of my application for a patent, while in the office of my counsel, Mr. Joseph Lyons, I happened to look through a German scientific book in his possession, and reading up about the phonograph, I came across a remark stating that on April 30,

1877, one, Chas. Cros, deposited at the French Academy of Science a sealed paper which, when opened and read at a subsequent session during that year, was found to contain a description of the author's idea that a photo-engraved phonautographic record, either in relief or intaglio, might be utilized 'for reacting through a stylus on a diaphragm, and by this reaction ought to reproduce the original sound.'

"Surprised as I was at this discovery, I requested Mr. Lyons to find out through his friends in Paris whether and to what extent Mr. Cros had ever carried his idea into practice, and an answer has since come to the effect that Mr. Cros never put his idea into practical operation.

"Whether he was taken aback by the *éclat* which the phonograph produced soon afterward; whether he became discouraged at the practical difficulties, of which I have found many at the outset of all my experiments; or whether he did not appreciate the peculiar advantage of the phonautogramic method—all this does not appear from the meagre accounts so far to hand.

"But although, viewed in the light of equity, he had virtually abandoned his invention at the time when I independently and without knowledge of his prior idea took up the same subject, the fact remains that to *Mr. Charles Cros belongs the honor of having first suggested the idea of, and feasible plan for, mechanically reproducing speech once uttered.*"

As this statement has never been challenged since it was first made, I presume that it is substantially correct.

If we should attempt to carry out strictly the ideas of Mr. Cros, we would find many obstacles to obtaining practical results, and while undoubtedly the correctness of the general principle could be proved, the effects would not be as good even as those obtained by the original phonograph. Even with the application of the various improvements which I originally introduced, the process requires great care, and while this would not have been an obstacle on account of the great advances made in photo-engraving, I have now abandoned the original process altogether, and have substituted one of great rapidity and simplicity.

But to return to the phonograph, we find this apparatus remained in an unsatisfactory and unfinished condition for nearly nine years.

Among those who believed that ultimately the phonograph could be turned to practical account, was the well-known original patron of the speaking telephone, Mr. Gardiner G. Hubbard, and being also financially interested in it, he, in 1883 or thereabouts, caused the Volta Laboratory Co., an association originally founded by Prof. Bell as a laboratory, from the funds of the Volta Prize awarded to him by the French government, to provide ample funds for the purpose of making an extensive series of experiments with the phonograph.

Prominent among the scientists connected with the enterprise were Prof. Bell, Dr. Chichester A. Bell, and Mr. C. S. Tainter. After two years of ardent labors these gentlemen came to the conclusions:

First. That the indenting process had to be abandoned and an engraving process be substituted—*i. e.*, instead of pushing the record surface down with the stylus, as in the original phonograph, it should rather be dug out or graven into.

Second. That the best substance, answering also the various other requirements, was beeswax hardened by an admixture of paraffine, or other similar waxy substances.

Third. That loud speaking was impracticable, and that the ordinary conversational tone gave better results, although reducing the reproduction to the loudness merely of a good telephone message.

In Patent No. 341,214, of May 4, 1886, issued to Dr. Chichester A. Bell and Mr. C. S. Tainter, the following claims, among others, were granted:

"The method of forming a record of sounds by impressing sonorous vibrations upon a style, and thereby *cutting* in a solid body the record corresponding in form to the sound waves, in contradistinction to the formation of sound records by indenting a foil with a vibratory style, etc.

"3. The vibratory *cutting* style of a sound recorder; substantially as described.

"7. A sound record consisting of a tablet, or other solid body, having its surface *cut or engraved* with narrow lines of irregular and varied form, corresponding to sound waves substantially as described.

"9. The method of forming a sound or speech record, which

consists in engraving or cutting the same in wax, or a wax-like composition; substantially as described."

As a final result of all their labors, there issued in the spring of 1887, the graphophone, the first really practical apparatus of the phonograph type, and which was exhibited to admiring crowds in Washington and elsewhere.

To those who have never heard this instrument, I will repeat what I wrote about its performance in November, 1887, namely, that it appears to be the best instrument to take down business letters or dictations of any kind, in which the recognition matters little, so long as the words can be made out; also, that the reproduced sound is as loud as that of a good telephone message, but that the distortion produced by the engraving is sufficient to make the voice unrecognizable save to a strained imagination added to a previous knowledge of the author of the voice. The record ground of this machine is a thin pasteboard cylinder covered with wax.

Soon after the graphophone became generally known, Mr. Edison, evidently encouraged by the results obtained in this instrument, took again to experimenting with the phonograph, and, after trying wax covered with tin-foil for indentation, he abandoned that mode of recording, and also settled upon a cylinder of wax and the graving-out process, thus confirming the correctness of Bell and Tainter's conclusions, and the new Edison phonograph and the graphophone appear to be practically the same apparatus, differing only in form and motive power.

I now come to the subject of the evening, the Gramophone.

In my telephonic studies, I had become familiar with all the causes influencing the transmission and reproduction of the voice, and what had at all times struck me as forcibly as anything in telephonic phenomena, was the fact that the self-induction of long iron wires or of polarized electro-magnets acted so detrimentally upon the articulation. Electrical resistance alone would simply have weakened the sound, but self-induction meant retardation, and this distortion of the transmitted waves which varied in length and amplitude. To appreciate fully what an extremely small amount of energy ordinary speech possesses mechanically, let us consider a few well-known facts:

A puff of air, not strong enough to extinguish a candle-flame,

when blown across an empty bottle or into a whistle will produce a sound which may be heard over a hundred feet away. The amount of electricity needed to operate audibly a magneto-telephone, is said to be less than one-millionth part of the electricity of a standard Daniel cell.

In considering such and other facts it became evident to me that if such delicate energy, subdivided into maybe several hundred waves, should indent or engrave itself into a solid body, it needed but very slight mechanical resistance to modify considerably the character of the sound vibrations. For what self-induction is to the telephone circuit, the variable resistance which impressible material offers to indentation or engraving at various depths is to the phonograph record sheet. Neither is proportional in direct ratio to the expended energy and must give cause, aside from a reduction in size of the sound characters, also to a distortion of the same.

Your own Prof. Houston, in his learned remarks in the JOURNAL OF THE FRANKLIN INSTITUTE of January, 1888, says:

"The difficulties just pointed out, it would seem, must exist in any instrument, however improved in its mechanical structure, if it make the record on the Phonogram at right angles to the surface thereof. Of course, if a substance was discovered for such a surface, that offered a resistance to indentation exactly proportional to the depth of such indentation, the difficulty would, to a great extent, be removed."

All the experiments which were made with the phonograph and the graphophone, confirmed the correctness of all these assertions, for the louder it was necessary to speak when recording, the less distinct became the articulation of the reproduced sound.

A change for the better was, therefore, to be obtained:

First. By tracing the vibrations, as in the old phonautograph, parallel to the record sheet.

Second. By reducing the resistance offered by the record medium to as near to nothing as possible.

Both principles, although not emphasized, are contained in the Cros document; but for my part, I found that merely smoked surfaces were utterly impracticable, because, if sufficiently black for a photo-engraving, and with the extremely small sizes of

waves obtained with records that are adaptable for the reproduction of good articulate speech, the record lines were ragged, and, under a magnifying glass, looked like a set of parallel saws whose teeth would form a grating sound, which nearly drowned the articulation.

I observed, however, in my experiments, that the grayish deposit of lamp-black which is obtained from the centre of a kerosene flame was more oily and gave a somewhat sharper line than the deep black deposit caused by smoking with the top of the flame, and this led me to the highly beneficial process of oiling the plate prior to smoking the same, either by applying printers' ink or artists' paint by means of a printers' roller or by brushing oil over it. The smoke would then amalgamate with the oil and forms a *fatty ink* of a rather dry consistency, which, when crossed by a stylus, shows, even under a microscope, a sharply cut transparent line.

I still employ this process for small test plates and prepare them as follows: One part of paraffine oil is mixed with twenty parts of benzine or gasoline. This mixture is poured on and off a glass disk, when the benzine evaporates leaving an extremely thin layer of oil. This is held over a smoky flame and moved to and fro until the surface looks *just* dry. The application of artists' paint with a roller prior to smoking is still better.

I also adopted for the gramophone a disk of glass as a support for the smoke deposit, traced the sound record from below so that the displaced lamp-black should fall down, varnished it after the tracing was done and used this disk as a negative without, therefore, needing a camera or photographic chemicals outside of the chrome-gelatine or chrome-albumen used in developing a raised picture. I would refer, for a detailed account, to the already mentioned issues of *The Electrical World* and the JOURNAL OF THE FRANKLIN INSTITUTE.

The lesson of simplicity which the telephone was continuously preaching caused me at an early day to look for a simpler plan to attain my purpose, and in the specification originally filed by me I said:

"This record (meaning the phonautogram) may then be engraved either mechanically, *chemically*, or photo-chemically." And although for a long time without much hope for success, the

purely chemical process of direct etching haunted me continuously, and was repeatedly suggested by others.

But it was easier suggested than carried out, because under the principles of the gramophone the etching ground was to offer practically no resistance to the stylus, and to make one which had no resistance mechanically, but did resist the etching fluid after the tracing was done, was the problem to be solved.

You will readily see, that if we can cover, for instance, a polished metal plate with a delicate etching ground, trace in this a phonautogram and then immerse the plate in an etching fluid, the lines will be eaten in and the result will be a groove of even depth such as is required for reproduction; such a process, of course, would be much more direct and quicker than the photo-engraving method.

In nature provision seems to be made for all the wants of mankind, and confident in this belief, I kept on trying to find a trail which led to promising results, and I have the honor to-night, for the first time, to bring before you this latest achievement in the art of producing permanent sound records from which a reproduction can be obtained, if necessary, within fifteen or twenty minutes, and which can be accurately multiplied in any number, by the electrotype process. It may be termed, in short, *the art of etching the human voice.*

The etching ground which I use is also a fatty ink, and one of the best I have found thus far is made by digesting pure yellow beeswax in cold gasoline or benzine.

Benzine, in a cold state, will not dissolve all the elements of the wax, *but only a small part,* namely, that which combines with the yellow coloring principle, and the resultant and decanted extract is a clear solution of a golden hue, which gradually becomes bleached by exposure to light. The proportions which I use are one ounce of finely scraped wax to one pint of gasoline. The bottle containing the mixture must be repeatedly shaken, and, after the white residue has settled, the clear fluid is decanted or drawn off by a siphon.

I then take a polished metal plate, generally zinc, and flow the fluid on and off, as if I would coat with collodion. The benzine will quickly evaporate, and there remains a very thin layer of wax, iridescent under reflected light, not solid as a coating pro-

duced by immersion in a melted mass, but spongy or porous, and extremely sensitive to the lightest touch.

Partly on account of the too great sensitiveness of a single film, and also as an additional protection against the action of the acids employed in the subsequent etching, I may apply a second coating of the solution, and this double coat I find to answer all requirements.

The protection which this porous or spongy wax affords from the acid, is mostly due to the fact that watery solutions assume the spherical state on the film, while at the lines where the wax is disturbed the acid enters freely, and attacks the metal below.

A difficulty, which only a short time ago appeared insurmountable, was the accumulation at the point of the stylus, while tracing the sound record, of filamentary particles of dust which exist in the wax solution, and which being ever present in ordinary rooms, settle down and adhere to the film. These dust particles are so fine that they cannot, as a rule, be detected by the most searching inspection of the prepared plate; but they become very conspicuous, and a very serious source of annoyance when a long record is being made.

It must be borne in mind that the contact which the tracing stylus makes with the record surface, is obtained by the elastic pressure from a piece of hair-spring backed by a narrow blade of writing paper, and which pressure amounts to about five grains. Therefore, as this stylus passes through the fatty ink or other ground, and traces the fine undulatory line, the dust particles, as well as small portions of the displaced ink or wax adhere to and accumulate at the point of the stylus and are dragged along, and the record thereby becomes blurred and indistinct.

I have discovered an effective means for overcoming this difficulty, and it consists in applying to the record surface a fluid that slightly adheres to the etching ground, and keeps it wet while the record is being made. I have found commercial alcohol to be very effective for this purpose, and it is used by pouring it over the plate just before the sound record is made. The alcohol, of course, immediately commences to evaporate, but not rapidly enough to disappear entirely before the record is finished, and there is no difficulty in adding more alcohol while the plate revolves. Under this condition, the point of the stylus remains

perfectly clean, and it seems as if the dust particles had not been present at all.

The theory by which I explain this result is, that the alcohol, so to speak, lubricates both the surface and the stylus, and prevents the adhesion of the filaments to the latter. At any rate, the application is highly beneficial, and the resulting line is so sharp and fine that it has to be widened in the subsequent etching process, in order to permit the acid to bite at sufficient depth. It can also be proved that the resistance of the wax film is decreased by the presence of the alcohol, but when this has evaporated the wax film appears to be in precisely the same condition as before, even showing again the iridescent colors which disappeared on the application of the alcohol.

The film of wax being so thin, it is almost transparent, and if th erecord was made on this it could barely be detected. As, however, it is sometimes desirable to examine the record prior to etching the same, I can smoke the etching ground slightly by holding it high above burning camphor, so as to prevent a heating and melting of the spongy wax, and the alcohol poured afterwards over this smoked surface does not seem to wash off any of the soot particles.

We now come to the important process of etching the record. Etching is done on steel, copper, or brass with nitric acid, perchloride of iron, or with a mixture of muriatic acid and chlorate of potash known as Dutch mordant. In modern photo-engraving nearly all the etching is done on zinc by means of diluted nitric acid, and these materials are preferred on account of their being cheaper than any other, and zinc is a metal easily obtained with smooth and even facings. In etching, however, on zinc, it is necessary continually to brush away the hydrogen bubbles which form and adhere to the lines, and as the etching ground is usually of firm and solid material (like asphaltum, hard wax, pitch, or rosin mixtures) no harm results from the brushing necessary in order to obtain sharp edges along the lines.

Desiring to avail myself of the advantages offered in zinc plates, I soon found that no etching fluid was known that would be to zinc what perchloride of iron was to copper—namely, etch cleanly and without the appearance of hydrogen bubbles. To apply the brushing to the delicate spongy wax film

I employed was out of the question, as the first touch would wipe away the whole ground, and to permit the formation of hydrogen bubbles without brushing them away meant uneven and ragged lines and a distorted record.

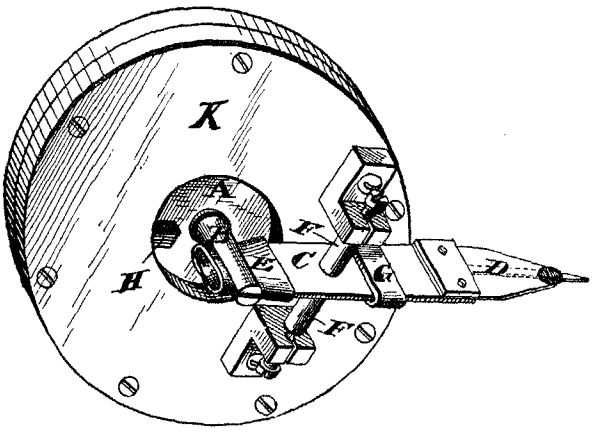
While studying this matter over it occurred to me to, so to speak, depolarize the zinc plate by adding to the acid, bichromate of soda which I thought might prove efficient, as it does in the galvanic battery, to prevent the appearance of the bubbles while etching the zinc. It took, however, a comparatively large quantity of the bichromate to answer my purpose, so much that I concluded that the mixture had all the conditions of a chromic acid, or at least of a mixture of chromic acid and nitrate of soda. When I thereupon substituted a solution of chromic acid pure and simple, I found this to be a most excellent etching fluid, and that is what I am now using—namely, a solution of one part by weight of dry chromic acid dissolved in three parts by weight of water. I use the commercial acid, such as can be obtained from Churchman & Co., of this city, at twenty-five cents a pound. Such a solution etches on zinc a sharp and clearly cut line, and no hydrogen appears during the etching.

The back of the zinc plate had previously been painted with protecting varnish or molten beeswax, and within from fifteen to twenty minutes from the time of immersion in the chromic acid solution, and without disturbing it a cleanly cut groove of sufficient depth is obtained for reproduction. This groove may then be deepened in the ordinary way of rebiting by covering the facing of the plate with rosin dust, heat the same, and then immerse in diluted nitric acid. Under these conditions the brush may be applied until the necessary depth is obtained, generally in about one to three minutes according to the strength of the etching fluid. I have used stronger solutions of chromic acid with no ill effects and a more rapid etching, and there seems to be a wide margin on this point, provided the plate is watched during the etching process. The lines very gradually widen in the course of the etching, but the upper edges of the grooves remain perfectly parallel and sharply defined.

Before proceeding with a practical demonstration of the whole process, I will now describe the most important apparatus of the gramophone, the recorder. The translation of the movements of

the diaphragm into the same movements at right angles, and with the extreme smallness of the motion and the liability of distorting them, adding to them, or detracting from their value in translating them, requires greater care to guard against error than an uninitiated observer would suppose, and when we examine the complex and extremely delicate mechanism which nature has provided in the human ear for giving a correct translation of air vibrations into nervous vibrations, it behooves us to be careful in the application of every day mechanics. Free as the telephone is, comparatively, from mechanical incumbrances, it is deficient in articulation of the consonants, and with the simplicity of mounting as required in the phonograph and graphophone, these difficulties of recording proper do not exist, and are shifted to the other portions of their construction and manipulation. In having attempted, therefore, to do justice to all sources of error I am not yet prepared to say that my present recording apparatus is constructed and adjusted to the greatest attainable correctness. Those who are familiar with the tediousness of original research will admit that a new subject of this kind cannot be solved in its entirety within the space of a few months, and what I bring before you to-night being the hasty results of a new machine finished but ten days

FIG. 2.



ago, should be measured rather by the possibilities it opens, than by the results so far attained, whatever merit you may accord to them.

My impression, however, is that there is very little of lost or added motion in my present apparatus, and whatever imperfections may exist must be looked for in the mode of reproducing the sound, rather than in the recorder (Fig. 2).

K is the diaphragm box; *A* is the centre portion of the diaphragm; *B* is a brass post screwed to the diaphragm and slotted above; *E* is a piece of rubber tubing held in the slot and holding one end of the stylus *C*. This stylus is made of stiff metal and is pivotted by the steel pivots *F F*. *D* is a blade of writing paper reinforced by a piece of hairspring which extends, and forms the tracing point. *G* is a piece of rubber tubing around the stylus which dampens its musical vibrations; *H* is a piece of felt damper between the diaphragm and the diaphragm box, which acts as a general damping device.

The whole is mounted on a sliding carriage, which is drawn by clock-work across the disk, while the latter revolves at the rate of about thirty revolutions per minute.

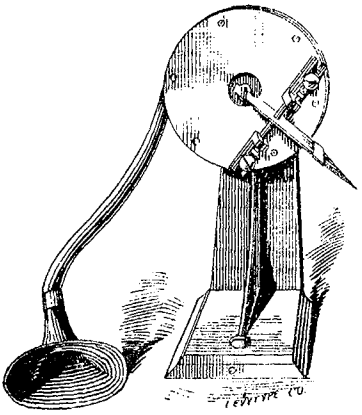
DEMONSTRATION.

While the plate is being etched I will now let you listen to some phonautograms which I prepared in Washington within the last two weeks. The reproducing apparatus, or sounder, is constructed on precisely the same principles as the recorder, but of smaller dimensions and with more rigid mountings, so rigid, in fact, that if it was used as a recorder it would barely show undulations on a smoked surface when shouting into it.

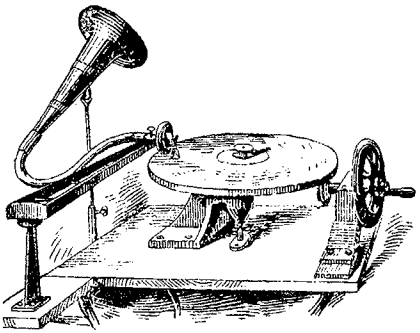
The stylus is tipped with iridium like the points of a gold pen, the object of this being to prevent abrasion by the continuous friction with the hard record.

In reproducing the sound, I find that it is louder with hard contact substances, like metal, than with soft ones like rubber or plaster-of-Paris. Hard metals like copper, nickel, or brass, sound louder than zinc or type-metal, but the scraping sound, which is due to friction, is also increased unless the record surface is smooth and very highly polished.

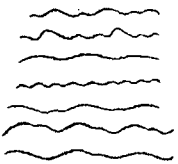
But when an iridium-pointed stylus is rubbed over clean glass a scraping sound is barely perceptible. I am now in communication with a firm that is making ornamental glass tiles by im-



Recording Diaphragm and Stylus.



Reproducing Apparatus.



Record lines (magnified 6 diameters).

pressing upon red-hot glass plates fancy designs in relief or intaglio by strong pressure. You will readily see that if on the same plan we can impress a matrix showing the sound record in raised lines upon a glass plate, we would get a groove, in glass giving a loud reproduction with a minimum of disturbing sound due to friction.

In the description of November 12, 1887, I advanced the idea of mounting the sounder on a carriage and rails, and have the record groove itself be the screw which was to guide the point of the stylus across the disk from periphery to centre. This has been improved upon by Mr. Werner Suess, the gentleman with me here to-night, and who is the mechanician of our little shop in Washington. He suggested to mount the sounder on a pivot at some distance from the disk and then let the reproducing groove guide the sounder across the disk over an arc of flat amplitude. This happy idea is embodied in the present apparatus, and is a very ingenious adaptation indeed.

REPRODUCTION.

It is, I trust, pardonable if I close by foreshadowing to a certain extent the practical applications of the gramophone.

A standard reproducing apparatus, simple in construction, and easily manipulated, will, at a moderate selling price, be placed on the market.

Those having one, may then buy an assortment of phonautograms, to be increased occasionally, comprising recitations, songs, and instrumental solos or orchestral pieces of every variety.

In each city there will be at least one office having a gramophone recorder with all the necessary outfits. There will be an acoustic cabinet, or acousticon, containing a very large funnel, or other sound concentrator, the narrow end of which ends in a tube leading to the recording diaphragm. At the wide opening of the funnel will be placed a piano, and back of it a semicircular wall for reflecting the sound into the funnel. Persons desirous of having their voice "taken" will step before the funnel, and, upon a given signal, sing or speak, or they may perform upon an instrument. While they are waiting the plate will be developed, and, when it is satisfactory, it is turned over to the electro-

typer, or to the glass moulder in charge, who will make as many copies as desired.

The electrotype shells are mounted on thick pasteboard, and this is backed by a stiff piece of sheet metal. There is another process which may be employed. Supposing that his Holiness, the Pope, should desire to send broadcast a pontifical blessing to his millions of believers, he may speak into the recorder, and the plate then, after the words are etched, is turned over to a plate-printer, who may, within a few hours, print thousands of phonautograms on translucent tracing paper. These printed phonautograms are then sent to the principal cities in the world, and upon arrival they are photo-engraved by simply using them as photograph positives. The resultant engraved plate is then copied, *ad infinitum*, by electrotyping, or glass moulding, and sold to those having standard reproducers.

Prominent singers, speakers, or performers, may derive an income from royalties on the sale of their phonautograms, and valuable plates may be printed and registered to protect against unauthorized publication.

Collections of phonautograms may become very valuable, and whole evenings will be spent at home going through a long list of interesting performances. Who will deny the beneficial influence which civilization will experience when the voices of dear relatives and friends long ago departed, the utterances of the great men and women who lived centuries before, the radiant songs of Patti, Campanini, Nieman, and others, the dramatic voices of Booth, Irving, and Bernhardt, and the humor of Whitcomb Riley can be heard and re-heard in every well-furnished parlor?

Future generations will be able to condense within the space of twenty minutes a tone picture of a single lifetime. Five minutes of the child's prattle, five of the boy's exultations, five of the man's reflections, and five of the feeble utterances from the death-bed. Will it not be like holding communion even with immortality?

POSTSCRIPT: One of the peculiarities inherent with the gramophone is the possibility to enlarge the original sound by enlarging the printed vibratory characters of speech and then photo-engrave

the same. In this manner it should be possible to get the reproduction at a much greater volume than the original sound. It would be interesting if some day speakers in a large hall would prefer to do their talking by machine, or to send speeches to a convention which they were unable to attend in person.

E. B.

[At the close of the paper and after the exhibition of the apparatus, Prof. E. J. HOUSTON moved a vote of thanks to MR. BERLINER for his interesting and valuable communication. The motion was carried unanimously, and the meeting was adjourned.]

THE PILOT CHART OF THE NORTH ATLANTIC OCEAN,

ISSUED MONTHLY BY THE UNITED STATES HYDROGRAPHIC OFFICE.

BY EVERETT HAYDEN, in charge of the Division of Marine Meteorology, United States Hydrographic Office.

[*A Lecture delivered before the* FRANKLIN INSTITUTE, *January 27, 1888.*]

Concluded from Vol. CXXV., page 278.

Perhaps the most characteristic as well as the most important data published on the chart are the "red data," comprising as they do all matters of special immediate importance and interest. The final proof of this impression is corrected and revised at the last moment before going to press, for this portion of the chart aims to give the latest and most trustworthy *news* regarding various subjects of great importance to navigators. The long list of Notices to Mariners gives, in brief, the title of each notice published during the month just passed, indexed in such a way that each one can be readily referred to and called for by number. These notices can be obtained, free of charge, at any branch hydrographic office, and the master of a vessel about to sail for a distant port can consult this list and obtain the latest information regarding the navigation of the waters which he has to traverse.