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Thos. A. Edison, Esq.,
In all appreciation,
From the author.

THE

REPRODUCTION OF SOUND.

Being a description of the Mechanical Appliances and Technical Processes employed in the art.

BY

HENRY SEYMOUR.

LONDON:
W. B. TATTERSALL, Ltd.,
40/43, Fleet Street, E.C. 4.

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INTRODUCTION.

A BRIEF HISTORICAL SURVEY.

In his Letters on Natural Magic, Sir David Brewster, animadverting upon the apparatus contrived by Kempelin, and upon the more recent researches of M. Savart, relative to the mechanism of the human voice, ventured to express an opinion that before the close of the last century a singing and talking machine would be numbered amongst the conquests of science. At the time of writing we have lived to see the realisation of Sir David's dream, and, indeed, to find its object a common acquisition to the homes of the people in every country within the pale of civilisation, to minister to the musical sense and provide culture and entertainment to almost every class of society.

In Brewster's day, however, it was not so difficult for men of scientific insight to hazard so certain a prediction, because the large array of scientific knowledge already at hand only needed some sort of ordered classification and synthetic deduction to make such a proposition more than mere hypothetical conjecture. We are justified in believing that the talking machine, in some form or other, was already an accomplished fact long before. There is the oft-quoted statue of Memnon, one of the twin colossi at Thebes, which is reputed by Strabo, Pliny the Elder, Tacitus, and other equally high authorities, to have given forth articulate utterance in resemblance of the human voice. This statue dates from the 18th Egyptian dynasty, and, therefore, can boast an antiquity of at least a thousand years before the Christian era. A great deal of speculation has engaged the minds of enquirers as to the manner of mechanism by which the articulate speech of the statue was occasioned, but the explanation has been left in a great deal of obscurity. The evidence seems to indicate the extreme probability that the vocal attribute possessed by this monument of architectural and sculptural grandeur was unknown alike to the classic artist who fashioned it and to the King whom it symbolized.* Perhaps the most extraordinary circumstance in connection with its history is that nothing appears to have been known of its ability to speak until the time of Strabo, when Egypt was in the hands of the Romans. The earliest inscription in cuniform upon its base bears evidence only of the date of Nero's time; and a fearful earthquake, occurring at Thebes. B.C. 27, is supposed to have been intimately connected with the acquisition of the vocal faculty. The upper portion of the stone was shattered by the seismatical disturbance, and for centuries it remained a *torso*. It was credited with having emitted a musical

*Amunhoph the Third. *See* D. Roberts', R.A , "Holy Land."

tone during this period at certain intervals: *Dimidio magicæ resonabant Memnone chordæ.* The restoration of the statue, in honour of its tradition, took place about A.D. 174, but thenceforth Memnon has been dumb.

It is interesting to note that Sir Robert Hart, returning after many years' sojourn amongst the Chinese, informs us that their books deal with every conceivable subject, and that, nearly half a century before the first phonograph found its way to Pekin, the Governor, Kwang Tung, personally told him that an ancient book dating back 2,000 years before relates how, a thousand years before that time, a certain Chinese prince sent messages to a brother prince by speaking them into a curiously shaped box; and also, how the recipient, on opening it, heard with his own ears the actual words and voice of the sender. Have we moderns merely discovered a lost art?

I have been unable to find an authentic account of any talking apparatus in Europe dating earlier than the 13th century, the most notable being that of Roger Bacon. Vaucanson's "duck," an automaton which "quacked" in a remarkably realistic fashion, was constructed about the middle of the 16th century, and was said to have performed many other extraordinary mechanical feats, such as flapping its wings and "eating" morsels of food. The Imperial Academy of Sciences at St. Petersburg offered a prize respecting the nature of vowel sounds, which brought into existence a machine invented by Kratzenstein in 1779, by the operation of which it was demonstrated that the vowel sounds could be properly pronounced by mechanical agencies when air was passed through a reed into cavities of various forms and sizes. This inventor was nevertheless superseded by Kempelin, referred to by Sir David Brewster, who applied the principle of the reed to a single cavity, analogous to the oral cavity, and by a dexterous use of his hand was enabled to produce the various modifications of form and size necessary to utter the vowels successively. He subsequently elaborated a contrivance which, by means of levers, tubes, and bellows, enabled a complete sentence to be distinctly articulated.

Then came Faber's celebrated "talking machine," in 1860. This was an elaborate model whose vocal abilities were produced by means of air in tubes, flexible rubber lips and tongue, with an ingenious mechanism concealed in the trunk operated by a keyboard. The vowels and consonants were controlled with considerable accuracy, while a vibrating ivory reed was mounted in the throat to form the vocal chords. The size and shape of its oral cavity could be instantly modified by a lever device; a tiny windmill, turning also in the throat, was controlled to roll the *r*, while the rubber tongue and lips expressed the consonants.

Experiments belonging to an altogether different category were now being made in acoustics and electricity. The automata referred to in the foregoing were contrivances designed to produce speech, whereas the newer school of experimentalists were content to devote themselves to the far more profitable and interesting technique of sound reproduction.

Chladni, the father of modern acoustics, was one of the earliest to formulate some definite conclusions concerning the phenomenon of sound. Professor Tyndall tells us that before Chladni's time, Lichtenberg made an experiment of scattering an electrified powder over an electrified resin cake, the arrangement of the powder revealing the electric condition of the surface. This experiment suggested to Chladni the idea of rendering sonorous vibrations visible by means of sand strewn upon the surface of the vibrating body. So far back as the latter part of the 18th century he applied himself to the study of this subject, and by means of vibrating plates he discovered the principles of motion which govern sounds of the harmonious series, rendering visible their nodal signs. Other workers in this field followed along the same lines with much diligence; and, coming to later times, the really wonderful experiments of Mrs. Watts-Hughes, in the voluntary control of these motions to produce definite designs and pictures in monochrome by the voice alone are worthy of note, although somewhat foreign to the present subject.

In 1856, M. Léon Scott evolved a contrivance which he called a "Phonautograph," and which was undoubtedly the prototype of the machine which Mr. Edison afterwards brought out in 1878. The Phonautograph was, I think, the first practical attempt in recent times to record speech through the agency of a diaphragm. The details were somewhat different to those associated with the Edison contrivance, but in general design of construction and motion it was almost identical. The method employed by Scott was to support a roller, having an extended spindle through its centre and forming its axis, upon two standards or supports, one extension of the spindle being furnished with a thread to engage with a corresponding female thread in one of the standards. A small handle attached to one end of the spindle enabled the drum to be revolved at any desired speed, the traverse movement to provide clearance being, of course, provided by the threaded spindle. The drum was covered with a sheet of paper, the surface of which was prepared with lamp-black; and at the perimeter of the same was placed a diaphragm of parchment held by a short piece of brass tube, upon one end of which it was stretched in the fashion of a drum-head, the other end of the tube being connected to a focussing chamber or barrel, made from plaster of Paris. Upon the centre of the flexible diaphragm was fixed with sealing wax a stubby hog's bristle; when the drum was revolved the bristle was in intimate contact with its carbonized surface, and removed the particles of lamp-black with which it came

in contact, leaving a distinct marking. It was found that when no sound was directed into the barrel or focussing chamber, and the drum was revolved at any speed, only a straight line was marked upon the paper; but when the drum was revolved at a given speed and sounds of various characters were concentrated in the direction of the flexible diaphragm, the marking or line would assume a wave-like form, and that these peculiar sinuosities varied in size and frequency as the sounds of speech differed in character. In fine, the waves varied with the pitch and intensity of the sound, but were invariably constant for the same sounds.

The Phonautograph, to be sure, furnished no means whereby these registered sounds might be re-spoken, and therefore its value as a scientific instrument was limited, because, although it made possible the ocular demonstration and definite analysis of peculiar sonorous vibrations, their synthesis, or ultimate solution, could never be correctly ascertained in the absence of means to make these vibrations manifest to the auditory sense. It belonged, therefore, to the purely theoretical category.

The study of vibrating diaphragms was being carried forward about this time by Philip Reiss, of Friedrichsdorf, who invented the telephone. The audible reproduction of sound was demonstrated by the transmission of sonorous vibrations from one diaphragm to another through the medium of a wire and agencies of the galvanic current and electro-magnets. Advances in the study of electricity brought additional developments in acoustics, and the telephone, as improved by Gray, Bell, and others, was unquestionably the parent of the phonograph. In 1863 a patent was taken out by Mr. Fenby for an instrument which he called the *Phonograph*, providing for the electrical recording and reproducing of sound. Then followed Edison in 1878 with a machine which he described by the same name, but which was altogether different in conception and function. There has been some controversy as to whether Mr. Edison or M. Charles Cros was the originator of the phonograph. It is known that the latter deposited a description of a similar instrument with the French Academy of Sciences in April, 1877, which was certainly prior to the earliest patent specification relating to this invention filed by Mr. Edison. But the matter has never been satisfactorily cleared up, nor is it likely to be. In many another branch of research we find similar coincidences. There is really nothing remarkable in the fact that more than one investigator, thinking in the same mental groove, may come to coincident conclusions. When we remember the extraordinary example furnished by the simultaneous discoveries and conclusions by Darwin and Wallace in biology, as to the origin of species, which involved far greater mental effort and a comprehension of circumstances infinitely more complex than those connected with the

rationale of sound reproduction, we may well leave the double claim to priority as to the invention of the phonograph in a similar category. It is said that Mr. Edison discovered the principle of the phonograph by a mere accident, that whilst engaged in experiments with a machine intended to repeat Morse characters—recorded on paper by indentations which transferred their message to another circuit automatically—he noticed a humming noise of a musically rythmic character follow the rapid movement of the impressed paper. It is somewhat difficult to connect the invention of the phonograph with data of that character, for there would be little resemblance to human speech in the rapid motion, under an engaging stylus, of ordinary Morse characters embossed. Besides, this fact was known long before, and Galileo produced musical sounds by passing a knife over the edge of a piastre, upon which Professor John Tyndall observed in his published lectures on "Sound" that "the minute serration of the coin indicated the periodic character of the motion, which consisted of a succession of taps quick enough to produce sonorous continuity." Robert Hooke also demonstrated in 1681 the making of musical and other sounds by the help of teeth in brass wheels, which teeth were made of equal size for the production of musical, and of unequal size for vocal, sounds. Later, Savart and many others exhibited the same principle in various ways.

The Phonograph invented by Mr. Edison was in many respects similar in construction to the Phonautograph designed by M. Léon Scott. The method of securing the record was, of course, different. The roller or drum was spirally grooved and covered with tin-foil. A steel point was attached to the centre of the diaphragm, and the whole was adjusted so that when the drum was evenly revolved by means of the crank it moved also laterally through the instrumentality of a feed device similar to Scott's, and whose thread was identical with the spiral groove of the drum. When, therefore, the drum was rotated and the stylus was brought into intimate contact with the foil, it was able to freely indent the same when impelled by the vibratory movements of the diaphragm to do so. The record, when made, thus became an inherent part of the machine, and consisted of a number of minute indentations in the foil, following each other in the line of the spiral groove and varying in size, depth, and separating distance in accordance with the intensity and pitch of the sounds which were uttered. The same diaphragm which caused the sonorous vibrations to be im pressed upon the foil, automatically reproduced them when the stylus was made to traverse the same surface a second time, and by that means the vibratory motion given to the stylus by the indented foil, and conveyed thereby to the flexible diaphragm, re-converted them into the original sounds, or something

like the original sounds, which made them. I am inclined to regard the reproducing means of the Phonograph as being far more subtle than the recording means, depending, as it does, on a mere adverse vibratory thrust.

It will be readily understood that a metallic recording surface such as tin-foil offered considerable resistance to the extremely delicate motions of the recording stylus; and the character of the sounds emitted in the reproduction was comparatively feeble, bearing no natural resemblance to the power or tonal complexity of the original speech. A marked improvement was effected in this particular by the employment of a conical amplifying tube, the smaller opening of which was attached to the orifice of the diaphragm box, and which gave increased strength and tone to reproductions with its aid. Nevertheless, they were at best but a mere caricature of the original, and it is small wonder that the Phonograph was regarded for several years simply as a scientific novelty.

The subsequent invention and improvement of the "wax" blank by Bell and Tainter, together with the employment of a sapphire stylus, shaped as a gouge to cleave into the substance of the blank, enabled very superior results to be reached, and specially designed machines were at this time introduced for the reproduction of records so made. The Phonograph was gradually passing into desuetude when these improvements were made, and the public interest quickly revived. Manufacturing companies were formed to exploit the "talking" machine as a commercial commodity, and to produce records of vocal and instrumental music for the million. This was the seed which generated the great boom in the eighties and nineties. The Phonograph had become democratized.

At first, every record sold to the public was an original, or what is technically described as a "master," but means were soon found by which copies could be secured from the master, without appreciable injury. This was the period of the "duplicating" machine, now practically obsolete. This scheme had the effect of cheapening the cost of record production, and their prices were thereafter reduced to the public, by the inexorable law of competition. The patent monopolies, to be sure, held competition in check to a very considerable extent, but at the present time there are a few fundamental patents only which subsist, and competition may be said to be now in full swing.

The duplicating method by tracing was superseded by the electrotype method of covering the master with copper, and by that means of obtaining a metallic negative from which any number of moulded copies could be taken. The obvious advantages which this system possessed over the older method were that all copies were alike in every material particular; and the employment of harder wax in the

moulding not only increased the durability of the record, but considerably augmented its tone. Although Mr. Edison did not originate the moulding system he soon brought it to a very high state of perfection, when in 1900 he applied the vacuous deposit system in electrolysis to the production of record negatives. By this process, far greater fidelity to the original could be assured, as well as securing an ideal surface smoothness, for the metal is deposited in this way without granular texture. When, by this process, certain metals are employed, gold, perhaps, being preferable, they are reduced by a high tension current to a condition of metallic vapour and deposited upon the surface of the record as such. To the obvious advantages which the moulding of records brought about must not be overlooked the further reduction of their cost, which still further stimulated the public demand for them.

An important step in the development of other processes, or one which may be described as a divergence in processes, was that following on the lines of Scott in the form of the sinuous track and made practical by Berliner in the manufacture of the disc type of machine and records. His method, originally, was to engrave, with a stylus attached to a diaphragm and subsidiary apparatus, a helical groove upon a disc of zinc which had been previously coated with a thin film of viscous substance, and by arranging the position of the diaphragm and stylus so that the vibrations acting upon them might be transferred on either side, as it were, of the groove. When the record was completed it was represented as a wavy spiral track. The next step was to etch the record into the substance of the zinc by suitable acid, and when that was accomplished it could be reproduced with a diaphragm situated vertically, and having a lever support for the stylus. Alternately, the record made in zinc could be used for the purpose of producing a metallic negative by electro-deposition, from which many copies might be pressed in material, such as shellac and its compounds, which becomes plastic by heat, yet is hard when cold. The early samples of this method were of the crudest possible description, but great strides have been made since then in the technical improvement of the method, and it bids fair to supplant the cylinder system in popular favour.

The process of producing "masters" by etching on zinc has long been superseded by the superior method of cutting into a "wax" blank by means of a sapphire stylus. The record, when completed, is metalized by means of very fine graphite, and is "electrotyped" in a sulphate of copper solution in the usual way, subject to special appliances and management of current to ensure a rapid as well as a tough and fine grain deposition. From the "master" matrix thus obtained, any number of secondary or working matrices are able to be got, and the most perfect means known to this

end is the "lead" process invented by Dr. Eugen Albert, of Munich.

Since the introduction of the Berliner disc record, there have been other modifications introduced having relation to the form of record track and cut, which involved, of course, corresponding modifications in the reproducing means. The most notable, possibly, of these variations is the "phono-cut disc," which after a long series of experiments I practically worked out in the early nineties. Two British patent specifications of mine filed in 1903 refer to recording and reproducing means in connection with this type of disc. About a year later, Dr. Michælis introduced the "Neophone" to the public, which was the same system in all essential particulars, except that his records were pressed in stout strawboard discs coated with enamel modified with boracic acid, in respect of which materials for the record body he obtained a patent. Afterwards, Messrs Pathé, Frères, of Paris and London, adopted this method, pressing the records in the shellac composition; and other companies are now engaged in the manufacture of this type of disc record, which offers several advantages of utility over the needle-cut form of track, such as greater durability on account of its ability to be reproduced by means of a ball sapphire, and the comparative ease with which the record thread may be increased, other things remaining the same, thereby enabling a subject of longer duration to be recorded. In 1908 I filed a provisional specification only for a new form of track for the purpose of still further increasing the playing capacity of this type of record, the walls of which should assume two sides of an equilateral triangle in contradistinction to the conventional arc form. The application of this simple principle at once removes most of the mechanical difficulties associated with the earlier phono discs, and renders a far more perfect reproduction possible.

The "endless band" record, to which either of the aforementioned styles of track are applicable, is, so far, unknown to the public, although it has passed the experimental stage, and is quite a practicable proposition. There need be no limit put to the duration of records made on this principle. It is only necessary that the materials of which they are manufactured shall be flexible, in order to readily pass over two mandrils; and celluloid or cellulose substances are specially suitable for the purpose.

A number of other schemes have been elaborated which may be noticed. The manufacture of cylinder records in celluloid is one of these. In the year 1893, Lioret, of Paris, constructed mechanical dolls which contained a small phonograph and reproducing means. The record was pressed in celluloid from a steel pattern, and was cylindrical in form. The first patent to be applied for in England for pressing celluloid cylinder records from a metallic

negative, electrotyped from an original "wax" master, was by Mr. John Lewis-Young, in the early part of 1894. This was the only practicable method; and notwithstanding that the electrotype for duplicating purposes was suggested by Mr. Edison some 16 years earlier, it is a matter for observation that the process did not come into use for the duplication of "wax" records until about the year 1900. Two companies were afterwards formed to manufacture celluloid records under the patents of Petit and Lambert, but they were never technically or commercially successful, owing in a large measure to the harsh surface noises associated with their reproduction. In some other respects they possessed considerable advantages.

A more revolutionary departure from the conventional processes was made by Poulsen, in the invention of the "Telegraphone," which marked an entirely new development in the art of recording sound. By the agency of this wonderful instrument, variations of magnetism may be induced in a steel wire, ribbon, or disc, which correspond accurately with the vibrations of a diaphragm in a telephonic circuit. Records so made may be instantly erased, when desired, by de-magnetization. The operation of the instrument is as simple and perfect as its conception was scientifically ingenious, but up to the present moment no thoroughly complementary means have been devised to reproduce the recorded sounds, it being necessary to resort to the old-fashioned ear-tubes. The most fitting use to which the Telegraphone can be put, in its present stage, is the automatic registration of telephonic messages.

The recording of sound by the agency of light is still another notable accomplishment in this field of research. A considerable number of patents for various methods in sound photography have been granted, and special mention may be made to those of Morgan-Brown so far back as 1880; of Mercadier in the following year; of Bell, Le Pontois, and Poliakoff in 1886, 1888, and 1900 respectively. It was not until Cooke in 1901 suggested the feasibility of stereotyping sonorous vibrations after being photographed, however, that means were thought of for their mechanical reproduction. Cervenka constructed an apparatus on similar lines later, and demonstrated the method. The principle involved in most of these methods is to vary an otherwise constant beam of light passed through a condenser and reflecting upon a small mirror attached to a vibrating diaphragm, the reflected beam or "light pencil" being directed to impinge upon a blank with a sensitized surface. The recording machine is constructed much upon the same lines as those of the ordinary disc recording machine, with the addition, of course, that it is also a modified camera.

The "stereotype" method of producing record duplicates capable of being mechanically reproduced has now been abandoned. The most recent method is to record in

the form of a line of varying opacity, and to rotate or otherwise pass the record between a beam of focussed light falling on a selenium cell in circuit with a microphone. The light waves are by this means translated into sound waves again. Messrs. Hulsmeyer, Thompson, Pletts, and others have contributed to the development of this method, which cannot, however, be said to be yet perfect.

A modification in the process of recording has been invented by Messrs. Holden and Hansard, which consists in varying or cutting off the light beam by means of a hinged shutter actuated by the vibrations of a diaphragm Theoretically, the principle is analogous to that of the "Auxetophone," a compressed-air relay reproducing device for the ordinary gramophone, invented, or rather improved, by the Hon. C. A. Parsons. In the one instance a beam of condensed light, and in the other, a stream of compressed air is employed as the medium.

The great theoretical superiority of the photophone system lies in the absence of any sensible resisting obstacle between the recording diaphragm and the blank; the diaphragm is, consequently, free to vibrate in response to the most delicate sonorous impulses, and must necessarily record sounds in a more perfect manner. Add to this that the records may be made of paper, and that they would be subject to a comparatively insignificant amount of wear by ordinary usage—since the system no longer involves any frictional contact of the record with the reproducing means—and it is not at all extravagant to suggest that when the system is perfected it must entirely revolutionize the gramophone industry. Such a system would no longer require any expensive and elaborate machinery, involving many distinct arts, for the production of records; but the amateur would be able to make them for himself at home, and reproduce them almost immediately; or, alternatively, to make as many duplicates as he might choose in the ordinary manner of printing photographic positives from the original or negative plate, at a trifling cost.

The subtlety of the subject of sound reproduction and the possibilities of the wonderful age of invention in which we live compel the careful student to be cautious in predicting what particular form the final "talking" machine will take, or even of entertaining any belief that finality will ever be attained in any one form known at the present time. That improvements in many directions will be wrought in all existing forms there is no reason to doubt. The uses to which the art of sound reproduction may be applied are so diverse and various that it may well be regarded as one of the essential acquisitions of civilisation. In the teaching of languages and the study of elocution, the preservation of folk-lore, and as an aid to correct instruction in the training of songsters it possesses features of the highest educational value. And in furnishing entertainment of

every conceivable variety calculated to appeal to the auditory sense it is unique; and in the words of Mr. Edison, "by bringing within the reach of everyone accurate reproductions of the best music, it exerts, almost unconsciously, an elevating moral influence."

CHAPTER I.

THE PRODUCTION OF RECORD BLANKS.

A preliminary necessity in the making of talking machine records is the production of suitable blanks and the preparation of their surfaces. Probably no part of the record-making process has given rise to so much difficulty and annoyance as that of the blank-making department. A great deal of defective recording has been due to bad blanks, not to speak of a number of other bad qualities in records which unsuitable blanks have engendered.

In some cases the material has been too soft or too hard, too brittle or too greasy, and in others it has not been homogeneous, and has presented variations of density at the surface. Other troubles have arisen from its solubility in the acid bath, to which the record, when made, has to be transferred for the purpose of obtaining a metallic negative therefrom for duplicating purposes. From this cause a partial dissolution of the surface is occasioned, which is conveyed to the negative as roughness, and which, in turn, is passed on to the moulded positive record. The effect of this defect is at once manifested in the reproduction of the record as unpleasant foreign noises which are no inherent part of the record itself, and which

tend to mar any merit which it might otherwise possess.

Endless chemical experiments have been performed by those competent in such matters ere satisfactory compositions were reached, and even at the present time the art of making these wax-like compounds is a closely-guarded secret by a comparatively few chemists.

Now, in order to answer to the requirements of the recording and electrolytic processes, the material of which the blank shall be composed must possess certain well-defined qualities. It must be quite homogeneous and cohesive, and yet be capable of being cut with the recording stylus in a perfectly clean manner, without clogging. The shavings from the cleavage must partake of such a character that they clear the stylus as rapidly as they are made thereby. The weak force of the sonorous vibrations which actuate the stylus from the recording diaphragm necessitate that the density of the material shall be commensurate with the means; and while not being too hard or too resisting, it shall nevertheless be stable enough to withstand handling and to retain its form and general intrinsic qualities through all ordinary changes of atmosphere and temperature.

It was found that most of the essential qualities sought for resided in certain animal, vegetable, and mineral waxes in some degree or other, but when these dissimilar products were mechanically amalgamated by heat, it was found that they were quite useless for all the purposes in view. Their ascertained melting points were altogether inconsistent, and in the mass, they lacked the all-important essential of homogenity.

It was next conceived to be possible to produce an insoluble soap which would ensure a *chemical* rather than a mechanical mixture of animal or vegetable and mineral waxes, such as a soap made by saponifying any fatty acid by means of an earthy alkali, and in which such metals as lead or aluminium might be incorporated. The admixture of tempering waxes, such as ceresine, paraffin, or other mineral equivalents, might be conveniently made after the process of saponification were effected.

The results were certainly successful. By continued improvements in the methods of combining the elements, the metal-soap blank found favour with the professional recorders, and some of the best work has been done with this medium: in fact, until comparatively recent times, no substitute has been sought, and for general excellence of work no substitute is necessary. Various formulæ are employed, of course, such compounds admitting of much diversity in proportions and such like, some manufacturers preferring one method and some another. But the essential composition is always the same. Preference is given, for example, by some makers to lead, and by others to aluminium, as the metallic element in the soap. The American Graphophone Co.,

by their patent taken out in 1898, claim to have originated the method of incorporating aluminium into the compound, either as metal or in the form of hydrate of alumina, and set forth some grounds for dispensing with lead or its compounds. But Mr. Watts did this long before, and it was well known to chemists that the amalgamation of aluminium with certain of the waxes gave them a very brilliant appearance. I am concerned more, however, to voice my objection to aluminium altogether as the metal ingredient of the record blank, and to examine the objections raised to the introduction of lead-oxide.

"Several practical difficulties," to quote the specification of the patent just referred to, "have been encountered in endeavouring to make tablets or blanks composed wholly, or in part, of soap. The chief difficulty has been that the surfaces of such tablets or blanks become coated, after a greater, or less, length of time, with a bluish film having the appearance of mould, and which has been termed 'efflorescence.' This is due to the presence in the material of hygroscopic compounds which, on being attacked by moisture, work out to and spread upon the surface. . . . Lead, in any form, as well as most of the salts of other metals which might be otherwise suitable for the purpose in view, give rise to the hygroscopic compounds. This is particularly true of stearates and acetates of lead.

"Another difficulty that arises is the formation of crystalline, or crystallizable, compounds in the operation of making soap. The object of introducing a metal (or metallic salt) is to prevent all tendency to crystallization, it being of the first importance to secure a composition which shall be and under all conditions remains perfectly amorphous, and which presents equal resistance to cutting in every direction. All ordinary commercial soaps have this tendency to crystallization in some degree, it not being possible to introduce sufficient sodium, or soda salt, to prevent all crystallization."

Two formulæ are given in the specification, both of which are said to have given satisfactory results.

FORMULA A.	lbs.
Stearic acid (free from oleic acid and glycerine)	408
Aluminic hydrate	7
Caustic soda lye	85

To this is added, for the purpose of tempering, paraffin, ozokerite, or similar materials, 72 lbs.

The method of manufacture may be given, which I have worked out experimentally. The caustic soda is mixed with water until a lye of 37.50 (Baume hydrometer) is obtained, and this is heated to its boiling point, about 242 deg. F. The aluminic hydrate is added and is rapidly assimilated in the lye. The stearic acid is melted and raised to a similar temperature when the lye is added thereto, in small quantities at a time and slowly. It will readily unite, but if too great a quantity be added at a time, or the temperature is excessive, violent ebullition will take place and cause the material to overrun the vessel in which it is heated, the danger of fire always requiring the observance of caution. When the saponification is completed, the remaining water in the mixture must be slowly evaporated, and this is best done by raising the temperature considerably, which, however, must never exceed 350 deg. F. in order that the composition shall not be charred. And under no circumstances whatever must the temperature of the mass reach, say, 500 deg. F., or it will flash by spontaneous combustion. When the water is quite expelled, which will be obvious by the absence of bubbles or steam and the reduction of the mass to an oleaginous condition, the tempering elements may be added, when the composition will be ready to strain and mould in the required shape.

FORMULA B.	lbs.
Stearic acid	300
Powdered aluminium	1.5
Caustic soda lye (37.5 B.)	9
Sal. soda dissolved in 12 gals. water	60
Ceresine	60

In this formula the sal. soda lye and caustic soda lye may be united before the aluminium is added, or the latter may be added to the caustic soda, and the two liquids then united. Instead of powdered aluminium, ordinary ingot may be used with results almost identical.

Record blanks made in accordance with either of the above methods certainly present a brilliant polish under the shaving knife and the recording sapphire, and probably keep their shape for a longer time than those in which the oxide or carbonate of lead is amalgamated. But the value of these properties is lost by the fact that the exposure to the air of blanks so composed induces the precipitation of the aluminium by the soda to their surfaces, which subsequently renders them extremely rough and noisy. I have tried numerous variations of the above formulæ in the hope of neutralizing this objectionable tendency, but without the least avail. I found that if I employed the aluminate of soda prepared from bauxite heated with soda in a reverberating furnace, far better results were obtained than by following the specified formula.

I append my own formula from which these results were reached:—

	Parts
S. stearine	28
Caustic soda	2
Aluminate of soda	1
Water	12
Bleached ceresine	6

The stearine is melted in the usual way, the caustic and aluminate sodas are boiled in the

water, and the lye is added slowly until the saponification is effected. The ceresine is heated separately and put in the soap afterwards. The aluminium, in being modified in this way, is more ductile, so to speak, or emollient, but nevertheless for the general purposes of the record blank I consider the lead soaps to be far preferable.

The objection urged by the American Graphophone Co. against the use of lead soaps for blanks is not well founded. The fact that the earlier lead soaps were improperly made, and that they were commonly associated with surface bloom or "efflorescence," or with crystallizable compounds in their substance, had nothing to do with the employment of lead. The first-named defect was due entirely to the presence of water in the compound which had not been sufficiently evaporated in the process, and which very naturally sweated out upon the surface. To have remedied this it would have been only necessary to allow the mass to simmer for a more extended time. The second-named defect was due to an excessive temperature in the saponification, by which the water of the lye was separated from the soda and driven off before it had completed its work of attacking the stearic acid. The "crystallizable compounds" consisted of nothing more than conglomerations of free soda, and the addition of water to the mixture with a further simmering would be sufficient to get rid of the trouble.

Another formula for blanks which is worthy of notice and consideration is one patented in 1901 by the National Phonograph Co., of the United States. The composition consists of an alkaline soap of higher fatty acids of the acetic series, such as a stereate or palmitate, or both, of an alkali, as soda; a lead soap of higher fatty acids of the acetic series, as, for example, a stereate or palmitate, or both, of lead; oleate of lead, a resinous substance, such as colophony, gum copal or gum kauri, and preferably a hydrocarbon, such as paraffin, ozokerite, or ceresine.

FORMULA:

Stereate and palmitate of soda, containing about 6.9 parts of sodium oxide (Na_2O) = 96 parts.
Stereate and palmitate of lead, containing about 21 parts of lead oxide (PbO) = 73 parts.
Oleate of lead, containing about 2.5 parts lead oxide = 9 parts.
Colophony = 10 parts.
Ceresine = 2 parts.

It is claimed that the above proportions by weight produce a composition which is absolutely non-crystalline in character, hard, perfectly smooth, and more or less transparent. The proportions named may, of course, be varied, and the ceresine may be omitted if a harder composition is required, or the oleate of lead may be reduced.

One of the most satisfactory compositions, however, which I have used, which has the merit of being cheap and comparatively easy to prepare, and which I worked out in a number of classified experiments and put to the various requisite tests, is embodied in the following formula.

FORMULA:

S. stearine	56	parts.
Caustic soda (98% pure)...	$3\frac{1}{2}$	„
Dissolved in water, about	15	„
Red lead	3	„
Paraffin wax	16	„
Japan wax	2	„

The stearine is melted in an enamelled vessel for preference. The caustic soda is dissolved in the water, after which the saponification is proceeded with. The precaution as to adding the lye slowly must be remembered, and when every trace of water has been slowly evaporated on the completion of the saponification, the lead, which is in the form of powder, may be thoroughly mixed with a small quantity of the molten soap in order to facilitate its absorption by the mass. It can then be very slowly added to the mass by means of a small ladle, when its chemical absorption will be gradually apparent by the mass changing colour from a bright red to that of a light limpid gamboge. As this takes place, a further addition of the red lead mixture can be made to the mass, until the whole is properly incorporated. As soon as this process is completed, the addition of the paraffin and Japan waxes may be made, and when thoroughly amalgamated the composition is ready for straining and moulding.

Almost any fine bronze gauze, or fabric such as swansdown, is suitable for straining. The latter is finer than the finest mesh in metal gauze obtainable, but requires to be frequently renewed. Of the metal gauzes, bronze is woven finer than copper, while the latter is somewhat cheaper and more easy to procure. A double layer of copper gauze is better than a single layer. Care and cleanliness at this stage become extremely important, as the smallest particle of dust or other foreign substance may prove a source of incalculable mischief in the subsequent treatment of shaving the blank surface and in the recording.

I may here remark that the above formula is specially applicable for blanks of the cylinder type, and for those of the disc type requiring to be recorded by the cylinder method. Blanks for the recording of the Berliner or "needle" type of record, which involves a practically constant depth of track with lateral or sinuous wave markings in contradistinction to the previously-mentioned type involving a variable depth of track corresponding to the wave motions, require a somewhat softer medium, and the proportions of the tempering waxes

should be accordingly increased, unless means are taken prior to recording to warm them, by a special apparatus to be described hereafter.

The latest composition to be introduced to the trade by German chemists consists of ozokerite and paraffin waxes in about the proportions of two to one respectively. This is very homogeneous, both belonging to the same series of mineral waxes, the former presenting a brilliant surface in cutting, while the latter is used only as a tempering medium. No composition could be more satisfactory for the recording of "needle" discs, nor for the subsequent treatment in the electrolytic bath for the production of metallic negatives, and the only serious drawback in connection with it is the difficulty of shaving its recording surface expeditiously on account of its brittle character, and its consequent disposition to fracture if the shaving sapphire be depressed into its substance to the ordinary depth usual with the soap blanks. The immense advantage of this composition resides in the fact that all the care and difficulty attendant upon saponification is dispensed with, as not only is it impossible to saponify the mineral waxes, but it is unnecessary to do so. By a process unknown in this country, blanks moulded in this composition are specially treated with regard to their recording surfaces, and are polished by frictional means, which effect a more beautiful surface than has been as yet possible to obtain with the conventional shaving blade. It is practically impossible to record upon these blanks, however, unless they are artificially heated throughout to a temperature about 80 degrees Fah., when they behave perfectly under the influence of the recording stylus.

CHAPTER II.

THE MOULDING OF BLANKS.

In the moulding and shaping of blanks for cylinder records a good number of appliances are required. First, there is the mould itself,

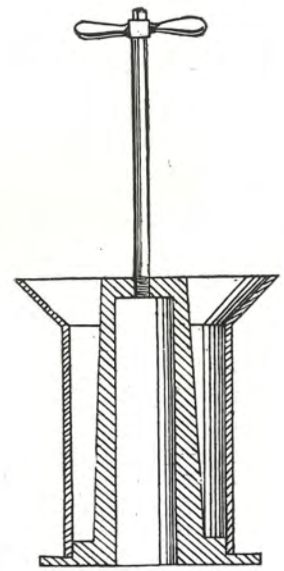


FIG. 1.

which is usually constructed of brass, in two parts—the outer mould and the core. The best type of mould for all practical purposes is that illustrated in Fig. 1. In this form, the base is one with the core, and the former has a boss at its periphery, upon which the bottom end of the outer cylinder fits tightly, but is detachable. On the upper end of the cylinder is a cup extension

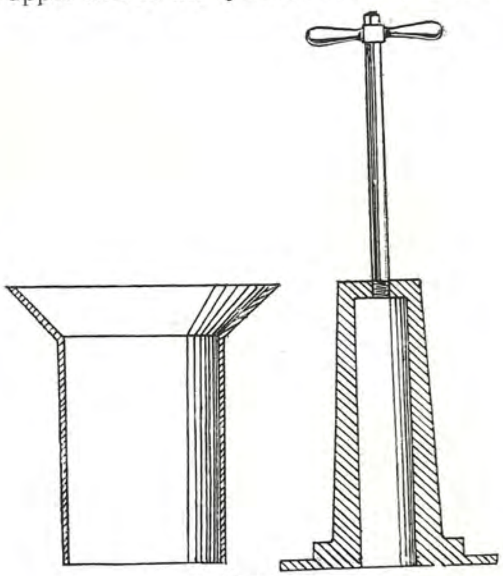


FIG. 2.

to hold a small surplus of molten "wax," which must be allowed for on account of the contractile property of stearine on cooling. The handle is attached to the top of the core for the purpose of lifting the mould in and out of the molten material in the vat, and is lengthened so that the heat is not readily con-

veyed to the hand. The core, which is a stout length of tube turned taperwise upon its exterior, has, in one form, a coarse thread cut into its surface, for the object of withdrawing it easily from the blank when set by sufficient cooling. The base has a hole in its centre as large as the inside of the core tube, which allows a current of air to pass through and facilitate the cooling, and to permit of the extraction of the core before the blank is removed from the outer cylinder, which can only be done when a certain degree of contraction in

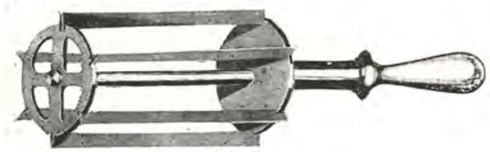


FIG. 3.

the mass has taken place. Fig. 2 represents the parts of the mould separated.

Second, there is the reamer, a tool having several steel blades, and which when the substantial contraction of the material has ceased, after being released in the solid form from the cylindrical mould, is passed through the blank and given a few turns to cut away such amount of the raised wax spiral as may be necessary to enable the blank to snugly fit the standard tapered mandril of the recording and reproducing machines. It need scarcely be remarked that the aforementioned steel blades should be carefully adjusted so as to present the precise taper of the mandril. (See Fig. 3.)

Third, the trimming and shaping machine is called into requisition. This is virtually the body or upper portion of a cylinder reproducing machine analogous in design and operation to that of the Edison "Triumph" type, the pulley of the mandril shaft being connected by a belt or cord to any convenient source of motion. The mandril is required to be somewhat shorter than the average, so that the two ends of the blank may overlap its extremities at both ends. The ends of the blank may, on that account, be more conveniently cut true by any ordinary steel dividing tool to its required length, and turned clean to right angles, or bevelled as desired. It must be remembered that the recording blank should be at least half-an-inch longer than the record from which moulded duplicates are required, to provide sufficient length for making true the ends of the matrix, or metallic negative, after the treatment of the record, when made, in the depositing bath.

The blank is now assumed to be ready for shaping, which consists of a preliminary shaving of its surface to nearly its required diameter, and this is done by a transverse steel blade capable of every adjustment, being rigidly affixed in its bearings to the carrier arm, and being actuated in its traverse motion by

the feed screw of the machine. This preliminary shaving should be carried out before the moulded blank is quite cold, otherwise it will not be possible to take approximately deep cuts, in order to save much time, without fracturing the surface of the blank, and thereby making the recording of it difficult if not impossible. The final shaving by the sapphire blade may be left for a lower temperature. Indeed, if a brilliantly polished surface is required it is quite necessary that the blank shall present a temperature not exceeding 75 Fah.

The principal point to attend in the moulding of blanks is the heating of the moulds on a hot plate or other device before dipping them into the hot blank material, or otherwise filling them. If this precaution is overlooked, the resultant blanks, when cold, will be found to contain air-holes which will render their shaving and recording out of the question. The moulds should always be as hot, approximately, as the molten material which is to fill them, if the defect referred to is to be avoided. It will amount to the same thing, to be sure, if the moulds are put into the molten material without being previously heated, provided they are permitted to remain therein for a sufficient length of time to allow the air bubbles, induced by the antagonistic temperatures, to be driven off before the moulds are removed from the mass. This is a bad practice, however, and little is saved.

We will next consider the composition, moulding and shaping of disc record blanks. It can scarcely be questioned, I think, that the metallic soaps so long in use have been superseded on the score of efficiency and general good service. But the tendency for cheapness has brought into the market a comparatively new compound for master disc records, which certainly has the merit of being an excellent medium for the depositing bath, since it undergoes no material change through the immersion. It is a compound of commercial brown ozokerite tempered with paraffin and Japan waxes. It presents a very brilliant polish in the shaving and recording cuts by reason of its close texture. But the substance is more difficult to handle than the metallic soaps, and there are greater risks in its employment. If shaved or recorded at too high a temperature, the material clogs and becomes "spongy"; on the other hand, if similarly treated at too low a temperature it fractures at the least provocation. This can be corrected to some extent by a larger addition of the tempering waxes, but too large a proportion of these will increase the porosity of the substance and destroy the chances of an ideal surface polish. It becomes a matter of urgent importance, therefore, that an artificial heating oven is employed in connection with this species of blank material, and this should be capable of the utmost management with respect to internal temperature. The usual means employed for the purpose is a sort

of cupboard made of wood, thin metal, or asbestos lined, and provided with lattice shelves to carry the blanks to be warmed. It has been found that electric radiators furnish the best source of heat, on account of their simplicity of regulation, otherwise steamheated pipes would serve admirably. Gas-jets would be equally simple, of course, to manipulate, but the combustion of the hydrogen of coal gas in oxygen or atmospheric air gives rise to vapour and induces "sweating" on the part of the blanks, causing their surfaces to be roughened as they dry off. In this, as in most other things, the slower is the surer method.

The inestimable advantage of the mineral wax over the metallic soap blanks lies in their easy and rapid production; the troublesome process of saponification being eliminated. The waxes are simply melted and mixed together, when the compound is ready for moulding. I have found that a very serviceable material in the construction of disc blank moulds is aluminium, spun to shape, and internally buffed and polished. They should be at least one-sixteenth of an inch in gauge, and for the standard 10-inch record they should have a diameter of 11 inches, to allow for shrinkage in the blank, and the necessity of trimming the matrix to dead true size in the lathe after the record has been electrotyped. The flange of the mould should be at right angles to the plane, as the shrinkage of the blank, on cooling, is ample for the purpose of removal from the mould. The flange should extend to at least 2 inches in height.

Blanks in the diameter referred to are usually cast $1\frac{1}{4}$ inches thick, which, when trued up and shaved for recording, are reduced to something like an inch, a necessity to safeguard against warping. As a ready conductor of heat aluminium is an excellent medium, and when the considerable quantity of molten wax contained within moulds made from this material is required to be cooled off as soon as possible, they give off the heat with greater freedom, in other words, in a shorter time. Moulds spun similarly from sheet brass may, of course, be used, but they are more expensive to make and less easy to handle.

So soon as the disc blank is ready to leave the mould being yet warm but set, it may be transferred to the shaping machine, or what amounts to the same thing, attached to the face-plate of a gap-bed lathe, and there planed both sides. This is done by means of a steel cutter attached to the slide-rest moving from the periphery to the centre in line with the axis. If the first side to be planed is to form the bottom of the finished blank, it will be necessary to plane the reverse side, as well as true the edge. before proceeding to bore the usual centre hole, the conventional size of which is five-sixteenths of an inch, otherwise it will not be truly at right angles with the face, which is of great importance in the recording. Some makers prefer that the centre hole of the blank,

which enables the recording turntable to hold the blank securely in position, should be bored completely through the blank. Others prefer to bore half way through from the bottom side and to use a short turntable pin, which is by far the preferable plan, as will be seen at a later stage. To facilitate the cooling of the blanks prior to their final shaving with the sapphire blade, they should not be placed in a draught of cold air, but simply be subjected to a general or regular lower temperature, as they may contract unevenly and split. It is important to note that disc blanks, when once made, especially if they are not permanently set, should be placed to set upon perfectly level surfaces, as they are apt to warp by their own dead weight. I have made it a practice to use small squares of plate-glass for this purpose, and also, subsequently, in the heating chamber, preparatory to recording, to ensure their plane surfaces being maintained throughout. Plate glass is generally dead-level, its surface being machine-ground after casting.

CHAPTER III.

THE SHAVING OF BLANKS.

The machine already referred to for the shaping and trimming of cylinder records, viz., that constructed upon the models of the well-known Edison "Triumph" or "Home" phonograph, is not to be surpassed, I think, for the purpose of finally shaving the cylindrical blank preparatory to recording (see Fig. 4). It must not be supposed, however, that the spring motors with which these phonograph

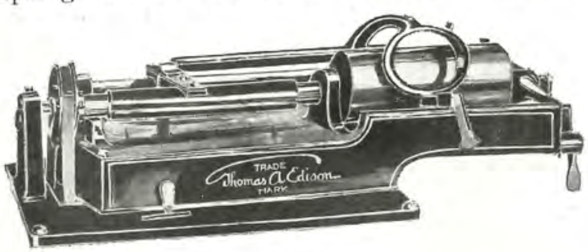


FIG. 4.

models are ordinarily equipped for reproducing purposes, are at all suitable for the work of blank shaving, at least in a commercial or professional way. The body of the machine should be connected, by way of the mandril pulley, to a small electric motor, the power being supplied from an accumulator, or, as

the case may be, from an electric circuit. The latter, of course, is not only the cheaper, but the less troublesome way. A motor of 4-volt capacity is ample for the purpose, and the consumption of current is comparatively insignificant. The most brilliant surfaces are only attained by revolving the mandril at high speed, and 500 revolutions per minute may be considered as below an excessive speed for this part of the work. There must also be a surplus of energy in the motor capacity to prevent slowing down on resistance, for the essence of a good shaving consists in a regular as well as a high velocity.

The machine for shaving must be very perfectly adjusted, and there must be no shake whatever about the bearings. It must be firmly fixed upon a solid bench or other foundation to avoid vibration. The ordinary "Triumph" or "Home" carrier-arm is next to useless for the purpose of carrying the shaving-blade setting, and a special, rather heavily-weighted, and rigid arm must be provided upon which a sleeved block should be fixed (being capable of universal adjustment) and through which should pass a straight stem carrying upon its lower extremity the cutting blade. For the purpose of regulating the depth of cut into the blank surface, this stem should be provided with an adjustable movement for lowering or raising the blade, as required. (See Figure 5.)

The cutting edge of the blade itself should assume a straight line, being bevelled for clearance. A sapphire shaving-blade is usually ground into sizes, ¼ inch square, 1-16 of an inch thick. It is set in a "holder," or small piece of brass, recessed, being joined by means of

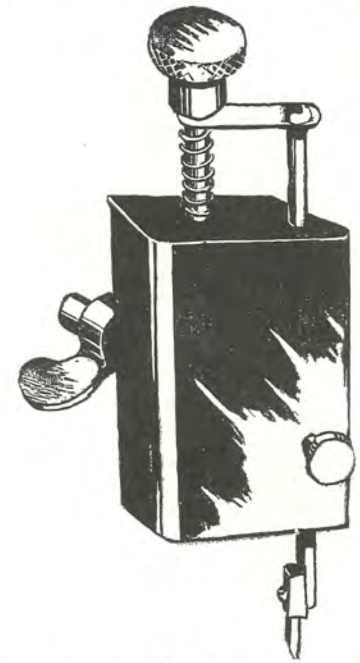


FIG. 5.

shellac. This is then screwed upon or otherwise attached to the stem before referred to.

It has been found to be advantageous, for the ultimate process of moulding records, to shave the blanks slightly taperwise, in order

that the moulded duplicate records may be more easily and rapidly extricated from the matrix moulds. This is best effected by having a separate slide bar to the shaving machine upon which the frontal part of the carriage travels laterally, and slightly drooping the lower end.

The back slide rod need not be interfered with, as there will be ample tension in the feed-nut spring to compensate for the slight divergence from the parallel in the two slide surfaces.

The most important point of all in the shaving of a cylinder blank is the disposition of the shaving blade to its surface. It should be so positioned that neither end of the straight cutting edge is ever in contact, and this may be done by adjusting the edge diagonally. For brilliant polishing, it should also be set to incline above rather than towards the axial line of the blank, and to do this effectively, the blade must be acutely bevelled for adequate clearance. By adopting these methods it will be found that the shavings will not clog, and that the actual shaving is performed by the central segment of the blade, which leaves less of a ridge than if either corner of the blade should come into contact. If, by a chance or careless adjustment, the corner of the blade is depressed to any sensible depth in the blank surface it will give rise to a continuous series of minute fractures, occasioned by chipping rather than by a clean cutting of the wax, which will make a smooth and noiseless surface impossible. Under all circumstances the front travelling edge of the blade should clear the blank, and the actual cutting should be done by the central, or rear section. If the blade, being straight-edged, as advised, is set level and perfectly parallel with the blank surface longitudinally, it will be next to impossible to get a clean and smooth surface, as the disposition of the shavings to jamb in these circumstances is exceedingly great.

It must be understood that no good shaving can be accomplished at all unless the cutting edge of the sapphire is faultlessly ground and polished. The edge of the best razor is blunt compared with what is requisite in the sapphire. It is only with some difficulty, moreover, that manufacturers are able to obtain what is required in this regard, as so much depends upon the selection of stone and so much upon the technical skill of the lapidary who fashions it into form. Shaving sapphires cost from three to five shillings each, and even then, the retention of their fine edge is of limited duration on account of the excessive friction to which they are subjected by the high rotating speed of the blank.

It is preferable to make several fine cuts in the blank rather than a fewer number of deep ones. It will prove to be the wiser economy. If the surface is fractured ever so little by too deep a cut, it will take many more cuts to remedy the defect. In addition, it may prove

to be necessary to cut below the regular or standard diameter to remove the fractures at all, in which case the blank will prove to be utterly useless on that account.

It has been found to be almost impossible to shave a cylinder blank effectively without leaving a trace of the shaving blade as a distinct track or spiral. It has therefore been found to be the best practice in shaving to adopt a feed movement in the shaving machine identical with that of the recording machine upon which the finished blank is to be recorded. It will be appreciated that the recording stylus will have a natural tendency to engage in the shaving track so formed, and if the record track cut by the recording stylus runs uniformly therewith, it will make no difference. But if the two tracks are in the least separated the one will present an obstruction to the other, and be responsible for bad appearances in the record surface as well as bad effects in the recording.

After the shaving is completed satisfactorily, and while the blank is still rotating on the machine with the blade released, a tuft of fine cotton wool may be passed along its surface to clear any slight vestige of shaving that may adhere or remain upon the surface. On no account should the least pressure be exerted, or the fine surface obtained by the shaving will be immediately destroyed.

The shaving of disc blanks is a far more difficult operation than the shaving of cylinders, and requires more care. The principal reason for this lies in the fact that the construction of the shaving machine adapted for wax discs must embrace something more than the ordinary mechanical principles which are called into requisition to perform work of a similar character in relation to materials other than wax and similar substances. A perfectly smooth surface in wax is infinitely more troublesome to obtain than in substances of greater density. The mechanical difficulty lies with the motion of the turntable, which is required to be heavy and absolutely rigid, and yet which must rotate with the greatest facility. The spindle of the table must be also heavy enough to adequately support the table and blank without spring and yet, if it be too heavy—requiring a bearing of equal proportions—much friction will be produced in the running which will make first-class shaving impossible at any considerable speed. As to the best velocity for securing good results, there is no determined rule, as variations in the wax compound make it necessary to suit the speed to the material; but, generally speaking, nothing like so high a velocity is necessary in the shaving of disc as in cylinder blanks. I have been able to get pretty highly surfaced blanks when the machine has been working at, approximately, 100 revolutions to the minute, but this has generally been the case with waxes only moderately tempered.

There are several types of shaving machine in use, the variations of which consist, mainly,

in the subordinate details of construction. Fundamentally, there are only two types, one having the turntable in the horizontal position and the other in the perpendicular. A great deal of objection has been urged by technical people to the horizontal table, and the machine with the vertical table finds the greatest favour with practical operators. It has been found that when a blank is shaved upon the horizontal table, the shavings have a tendency to get under the sapphire blade, since they remain upon the blank, unless blown off, during the entire operation, and in the case of their doing so they clog and bruise the polished surface after it has been obtained. I have found that this difficulty arises only in certain conditions, *viz.*, when the blanks are too soft and when the speed of rotation is too low. And to avoid this difficulty with the best blanks, it is necessary to adjust the cutting blade at a tangent to the line of the feed device. The shavings will then clear at once. But the far more serious drawback of the horizontal table is the dynamical effect which the required velocity of motion in the table has upon gravity. No matter how snugly the turntable-spindle is adjusted, the table is urged to sway when the speed is applied to it, and however slight this incidental movement may be, it is quite sufficient to prevent a perfectly plain surface from being secured. For this reason the vertical table is much to be preferred, as in that form neither of the evils already referred to are likely to arise. In principle, the vertical disc shaving machine is identical with the head of an engineer's lathe with a special face plate, and with a transverse feed device to hold the cutter. Fig. 6 illustrates a practical shaving machine of this type.

It will be seen that in this model, the feed device and block, carrying an adjustable blade, is one with an arm which swings open, when

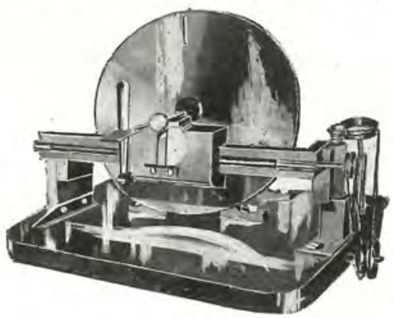


FIG. 6.

necessary, for the purpose of attaching the blank to the face prior to shaving, and for the removal of the same when completed. The feed is operated through pulleys and cord, as geared wheels are quite out of the question on account of the back-lash, the effects of which are plainly registered in the shaving. The main motion communicated to the table should always be direct from the countershaft, and in this form it is effected very simply. The dead weight of the table and blank is supported by bearings in which there is a minimum

of friction. There can be no tendency on the part of the table to rise, on the application of motion. The action is therefore more steady. The shavings from the blank clear themselves automatically by the effect of gravity.

In setting up the shaving machine, it should be heavily made and accurately fitted, no shake whatever appearing in the bearings at any point. It should be firmly bolted down on a concrete bed and be removed from all sources of extrinsic vibration. Whether the driving power be steam or electricity is of small moment, but the latter is preferable, and is more commonly employed. As electric motors generally run at high speed, it will be necessary to use a countershaft, not only for stopping and starting at will, but for reduction of speed to the turntable.

I have found that the best form of cutting edge to the sapphire for shaving cleanly is a slight curve on the advance side of a straight line. It should be so set in its metal shank that it can be adjusted easily, and when presented to the blank surface its curved edge should clear and the cutting be performed by the hind or straight edge.

The blade should not, as before remarked, be set parallel lengthwise to the feed slide, but set diagonally at an angle of about 45 degrees against the cut. The shaving will then be more clean and smooth. The same precautions against cutting too deeply apply equally to the disc as to the cylinder

The blank must be held firmly to the table by adequate clamps. Only one side of the blank, of course, will be required to be faced or shaved for the purpose of recording. The reverse side only needs to be level, so as to lay evenly upon the table of the recording machine, and that part of the operation was done, as the reader will remember, in the preliminary process of shaping.

When the blank is shaved with as high a polish as possible it is ready for the recording room, but it is advisable to lay it aside in a place protected from dust and other sources of possible injury for some days in order to "season;" in other words, to effect its molecular settlement. Some operators prefer to "season" the blank after the shaping process, and shave its surface subsequently. This is undoubtedly the better plan with the metallic soap blanks, but with the newer wax blanks the need is not so urgent. Until this settling process has taken place, however, the greatest care must be taken to place the blanks on perfectly flat surfaces to prevent sagging or warping. It is quite possible to record a blank if it is slightly concave or even warped, but if the record is to be carried through the process, as it is termed, that is to say, matrixed and pressed, then unheard-of troubles will ensue. The matrix will copy the defects referred to, and if the matrix is not dead true when it is put into the dies of the press a not very creditable piece of workmanship will be the grand result.

CHAPTER IV.

THE MAKING OF RECORDS.

The first necessity in the making of records is the provision of a suitable room having first-class acoustical properties. An ideal room for the purpose is one that is fairly lofty, say, ten or twelve feet from floor to ceiling, about the same width, and, perhaps, eighteen to twenty feet in length. Such a room would be none too large to secure good vocal results, and yet would be large enough to accommodate an orchestra or concert band containing such a number of performers as can be practically utilised to advantage. The room should be as bare of furniture as possible, and if the ceiling is domed or arched so much the better. The walls should be painted or lined with wood, well varnished, to aid sonorous reflection; and, in a room of such dimensions, it is preferable that neither hangings nor drapery shall be in evidence, as such absorbent materials will very considerably detract from the other advantages which such a room might possess. Needless to add, the room should be situated in a quiet locality, out of reach of disturbing noises, and away from heavy traffic, likely to set up subsidiary vibration. It should be well ventilated and be well warmed when the work is proceeding, and it has been ascertained by experience that a temperature of 70 or 80 degrees Fahrenheit is a satisfactory one in which to obtain the best results, other things being equal. The effect of heat upon sonorous conductivity is greater than is generally supposed, but if the atmosphere of the hot room is charged unduly with carbonic acid gas, arising from want of adequate ventilation, the effects will be lacking in brilliance in the recording.

Another important feature is the *wiring* of the recording room, this consisting of a series of fine steel wire-lengths stretched tightly across the room from side to side—that is to say, at right angles with the length of the recording horn, and arranged about twelve inches apart, being fixed, by means of stout screw eyes on one side of the room and furnished with adjustable sleeve fittings on the other, to facilitate the stretching of the wires up to their highest tension point. The height at which these wires must be fixed will be governed largely by convenience, as long as they are above the performers' heads, and yet are not too near the ceiling or roof. It is usual to arrange them some nine or ten feet from the floor level, and then they can be utilised for an additional purpose when it is necessary to record an instrumental combination, since, on account of the performers being required to vary their positions and heights very considerably, it would be extremely difficult to provide them, or many of them, with the ordinary floor-

stands to carry their sheet music. The practice is to use inverted music "stands" to hang from these wires, which are sufficiently numerous to allow of them being hung in any desirable position. It will be understood, of course, that these music-hangers will more or less detract from the main purpose of their existence, which is to augment or reinforce the volume of sound entering the recording horn, but in the case of a fairly strong instrumental body, this artificial aid to sonorous intensity by sympathetic vibration can well be dispensed with, or at least reduced.

In his excellent treatise on "Acoustics in relation to Architecture and Building," Mr. T. Roger Smith refers to the employment of auxiliary resonating means in chambers designed for auditory purposes by the adoption of wooden linings, which, theoretically, commends itself for approval, and in practice has seemed to afford great advantages where it has been introduced. He remarks upon the Conservatoire at Paris, the Ancient Theatre at Parma, the lecture theatre at the Royal Institution, and other places, all of which are conspicuous for their excellent effect upon sound. It is, indeed, a common custom in Italy to fix the orchestra of theatres over a species of hollow or trench, an arrangement which I have introduced into one of the London recording rooms recently, probably the first of its kind. The idea seemed to me to be a good one; and although it was carried out in a more or less experimental manner, the effect in recording turned out to be remarkable; in fact, other considerations had immediately to be taken into account and reckoned with. Recording diaphragms which were ordinarily correct under the old conditions were super-sensitive under these, and smaller recording horns were necessary also to employ, while all the remaining conditions were the same.

The best results in recording are obtained invariably when the weather is dry and bright. A humid atmosphere is greatly detrimental. Records made during fine weather always turn out better than when made in dull, wet, or foggy weather. They appear more sharp and brilliant. The cause of this, undoubtedly, is the effect of sultry conditions upon acoustic velocity. Most records are generally flat and dull by comparison, when made in such conditions, and the expert will be well advised to select his weather as far as he is able.

The furniture of the recording room is of a limited character. There should be no carpet upon the floor; in fact, the more bare the room the better. One of the requisites of a recording room is a pianoforte, an upright grand preferably, which should be raised some three feet from the floor by means of a strong wooden bench, designed to accommodate a seat for the pianist. The usual gauze cover at the back of the instrument should be removed, as the best pianoforte effects are secured from the back, and when the mouth of the recording

horn is approximately directed towards that part of the sounding board which is level with the keyboard in the front. It is also advisable to incline the recording horn somewhat in the direction of the upper register, as those octaves not only record much more easily, but the angle of the horn also tends to screen off the heavy, ponderous notes of the bass, which are generally productive of much clang. For the latter reason, further, it is not very customary to use the sustaining pedal, but to play *staccato* as much as possible; and the pianist must exercise his natural ingenuity in securing as good effects in light and shade as he is able, without recourse to the pedal. The secret lies in the "touch."

The difficulty in recording the pianoforte, satisfactorily, has led to its abandonment by most of the record manufacturers in favour of the orchestral accompaniment. All the stringed instruments are more or less weak in the capacity to actuate, the recording diaphragms, and undoubtedly the small orchestral combinations give far greater body, as well as a better artistic effect, to vocal interpretations. It was hoped that the grand piano might be utilised to better advantage in accompaniment than the upright, but the hope was altogether groundless, and the latter is conceded to be the better of the two for the purpose.

A great deal of the trouble connected with the recording of the pianoforte has been due to a bad selection of instrument. Yet it by no means follows that high-class and expensive instruments are better adapted to the work than the more simple in construction and moderate in price. The tone should be strong, and the hammers should be left comparatively hard, for recording work. I know of no better instruments for the recording room than those manufactured by Messrs. Rogers & Son, of Berners Street, W., under the technical supervision of Dr. Vincent, one of the best authorities on pianoforte construction. Although the pianoforte is now seldom used for the purpose of accompaniment in recording, it is still quite a necessity in the recording room for testing purposes, as all first tests of fitness on the part of vocalists are made with its aid.

Reverting to the comparative difficulty of recording stringed instruments, I may remark that the violin, in orchestral combinations, fails to figure very prominently in the record, and a recording room may be considered incomplete if amongst its accessories are not to be found one or more "Stroh" violins. This type of instrument is fitted with a diaphragm and small amplifying horn, which augments the natural intensity of the violin in a remarkable manner. Fig. 7 shows the manner of its construction.

One each of first and second violins and viola are all that are likely to be required for any combination, and by the aid of one of these the *pizzicato* effects can be obtained in the

record in any desired strength. Their cost is about £10 each.

Most record manufacturers also possess, as part of the establishment equipment, chime tubes, hung upon wooden framework, for purposes of church bell effects. These are metal

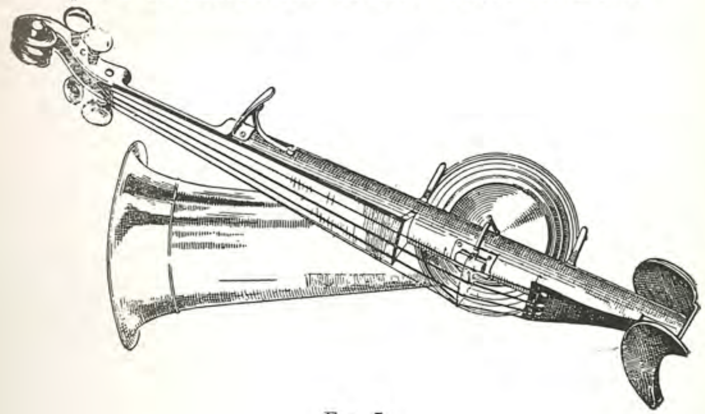


FIG. 7.

tubes, suspended from the frame, their lengths and diameters being varied to accord, on being struck, with the notes of the musical scale. They are made of various metals, as bronze, bell metal, or steel, and their cost varies from £10 to £50 for the set.

The next important part of the recording room furniture is a series of benches, of varying heights, to accommodate the bandsmen for the better focalisation of their respective instruments. The approximate proportions of these will be given presently when describing the relative positions which the instrumentalists should assume when in the act of making a record.

The most important part of the equipment is, of course, the recording machine. It is necessary that this should be *facile princeps.* It should be accurately adjusted and its driving mechanism should be perfectly regular and silent. For this reason the small electric motor was almost exclusively used at one time, but for other reasons it has now been all but generally discarded. For the standard cylinder records, perhaps no machine obtainable in the market is better qualified for good work in recording than the Edison type of reproducing machine known as the "Triumph," with the clock or spring motor. The Edison Co. employ this machine, I am informed, for the production of their master records. The electric motor was found to possess too many drawbacks in actual use to be reliable. The least dirt or grease in contact with the commutator or automatic governor brushes was sufficient to produce defective governing, and it is a *sine qua non* of recording that the machine shall govern with the greatest perfection. The accumulator, also, which was the source of current for the motor, would as often as not fall short of its requirements by reason of internal defects, which were not easy to discover without taking it to pieces. It is small wonder, therefore, that the spring motor (generally very

reliable) has entirely superseded the electric motor for actuating cylinder recording machines.

The "Triumph" body, as has already been pointed out, is supplied with a mandril shaft, supported between two centres, which is at the same time one with the feed thread for the lateral movement of the carriage, or carrier arm, to which the recording tool is attached. The spindle or shaft upon which the mandril is mounted is extended on one side of the mandril and the thread is cut upon it. Instead of the usual reproducing thread, a slightly coarser thread is necessary for recording masters which are required to be duplicated by moulding for the market. It is a necessity that the composition of which the moulded record is made shall sensibly contract on cooling, in order to release the record from the negative matrix, and this circumstance requires that the recording thread shall be slightly coarser, some two threads less in the hundred to the inch. A great deal depends, of course, upon the particular compound or substance of the moulding material. Some compositions shrink less than others, and especially those of the mineral wax series, which are now so much used for cheapness' sake, and for these perhaps one thread to the inch in the hundred will be a sufficient reduction.

These calculations are again subject to the particular method adopted for the duplication of "masters." In practice, it is always necessary to obtain more than one master of an individual or particular record, as the process of moulding from a single matrix would be far too slow to meet an ordinary demand for a record which happened to be popular. Some manufacturers record each subject upon several blanks, and make matrices from them as required. Others make the one master record and procure copies therefrom by the old method of mechanical duplication. But both of these methods are very unsatisfactory, since no two working masters are likely to be identical, and the most recent, as well as most perfect, scheme is that known in the trade as the "mother-matrix" process.

This process ensures all duplicates being exactly alike, and, consequently, far greater care and expense may be incurred in the production of the original. It is worked out in the following manner. Let us assume that the record when ready for sale is provided with a spiral track showing 100 lines to the inch, which was the standard thread before the "Amberol" or 200-thread record came into prominence. It matters little what the thread may be, as the same relation will hold equally good. The original master is recorded by means of a feed thread having 96 lines to the inch. This is thereupon electrotyped—that is, a metallic negative is grown upon it, and this is called the master matrix. A small number of casts in wax are made from this, and then the effect of the wax shrinkage gives 98

threads to the inch. These are similarly electrotyped, and become the working matrices; and the further shrinkage of the wax moulded in them results in the gain of two more threads to the inch, which is equal to the standard reproducing thread of 100.

The great advantage of this method lies in the fact that if, by accident or wear and tear, the working matrix gets destroyed, the original, or master matrix is still intact, being carefully stored away after the casting of the duplicate wax masters until it shall be required to similarly produce more. The master matrix is never used for any other purpose, and so, with reasonable care, there need be no limit put to the number of records which can be obtained from the original. The high fees paid to great artistes, and the difficulty of securing artistic results, as well as the desire to preserve the best specimens of the recorder's art, are all-sufficient reasons to commend the process in the interests of economy.

The only technical objection to be urged against its obvious advantages is that there are two metallic depositions involved, which must result in some loss of tone and detail. But the high pitch to which electrotyping has been brought in recent times reduces the value of this objection considerably; and moreover, by adopting the depositing method in the vacuum jar, as applied by Mr. Edison, the objection is practically removed altogether.

The construction of the "Triumph" body is, in many respects, well adapted for recording purposes. Almost any kind or type of carrier arm can be substituted with the greatest simplicity for that with which it is ordinarily furnished for reproducing purposes, if other types of recording apparatus are desired to be used. The arm may be easily detached by releasing a set screw which clamps it to the sliding sleeve with the feed nut and spring attached. Most professional recorders prefer

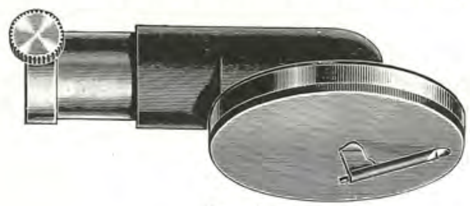


FIG. 8.

the trailing type of recorder (see Fig. 8), and this, when the "shell" is made of ebonite or vulcanite, will produce a far better tone than when all metal is employed.

It should be pointed out that the recording machine, before it is really ready for use, should be mounted upon a very solid table or bench, in order to avoid, as much as possible, any extraneous vibration in the room. A stout slab of marble or slate interposed between the bench and the machine will prove of assistance in preventing the loss of sound by absorption, after passing through the recording horn, inasmuch as the recording of sound by present

methods depends, to a large extent, on the molecular vibration of media employed in the process, as well as on the purely mechanical motion of the recording stylus. It is also preferable that the recording machine should be situated so that a solid partition or wall intervenes between it and the performers whose records are to be made, allowing only the horn, or part of it, to protrude through; and a small curtain is usually employed to stop up any superfluous opening, which latter must be large enough to permit of the side movement of the recording horn during the lateral movement of the recording device. The principal object of such a provision is to prevent the under-side of the diaphragm from being affected by the vibrations in the room, which are required to actuate the upper or inner side exclusively; whereas, if they are left free to communicate motion in all directions, without check, they are apt to neutralise the normal efficiency of any diaphragm very greatly; and in heavy band work it has been shown that the absence of some such provision either in this form or in some other, has had an injurious effect upon what otherwise might have been good work.

Let us next consider the making up of the recording tool itself. We will deal, in the first instance, with the recording of cylinders. It was customary for manipulators to equip reproducing machines with accessory recording apparatus in the earlier days of the business, so that those having the inclination might profitably spend their spare time in making amateur records at home. This was an excellent idea, which has done not a little to stimulate additional interest in the talking machine on the part of the general public. But recording apparatus sent out for amateur use were designed with that object alone in view. By mere chance, it occasionally happened that one of these recorders turned out to be equal in all respects for particular or individual voices to what the professional recorder would require in order to produce a record capable of satisfying the more exacting requirements of the market. In professional work, however, not one, but a considerable variety of diaphragms and recorders are requisite to suit different classes of work. For the higher registers, for instance, a much stouter diaphragm is needed than for the lower. The rapidity of vibratory frequency associated with a treble scale necessitates a rapid recovery of the diaphragm with each vibratory beat, and the stiffer the diaphragm the more rapid will be its recovery movement. It will be understood, therefore, that a diaphragm which is admirably suited for a piccolo solo or a soprano voice, will be altogether useless for much else, except, perhaps, a pianoforte solo. In a diameter of 33 millimetres (the standard Edison size) a diaphragm as stout as eight-thousandths of an inch is often required for such work, while a baritone, or even some tenor voices, may be perfectly accommodated by a diaphragm of half

that substance. Much depends again upon the manner in which the violinist or musician sings or plays in intelligent *rapport* with the diaphragm before him, and by a little practice it is comparatively easy to become instinctively acquainted with the limitations of a particular diaphragm, and by skilful handling to manipulate it for the production of first-class effects.

The control of the voice, indeed, in the making of records is the real secret of making good ones. The more the voice is kept under control, the greater may be the sensibility of the diaphragm employed, and, as a consequence, the greater will be the perfection reached in natural *timbre*. It is altogether a mistake to suppose that it is necessary for the singer or speaker to shout in order to obtain great volume. Strength of tone in the record acquired by such means is never pure, as the common result of too robust an expression is to shatter the diaphragm by over-vibration, which is productive of little else than discordant noise.

The keener the edge of the recording stylus, the greater will be the need for the foregoing precaution, on account of its disposition to cut more deeply. The part that a really first-class stylus plays in record-making is most important, and no good work can be accomplished without its aid. I shall never forget the revelation it was to me in the old days, when I happened to have the good luck to secure some specimens of recording points made by Jones, who manufactured the early recording sapphires for the Edison laboratory. I had been plodding on for a good time with experimental recording, using the best of the ordinary commercial sapphires supplied for the purpose, with results, from the professional point of view, which were not brilliant. But the substitution of the Jones sapphires at once supplied the missing link. I found them incomparable for cylinder recording of the concert size (5 inches in diameter blanks), and their secret lay, firstly, in their exquisite workmanship, and, secondly, but equally important, in their cutting edges being ground at the correct angle.

The microscopic keenness of edge, compared to which, as it has been said, the finest razor blade is as a saw, which is required to cut the metal soap blank both cleanly and evenly, requires that the very finest specimens of the stone shall be employed, and which are mostly free from flaws. Probably the Montana stones are the best for this purpose. Australia has not yet furnished the higher grades of stone suitable for this work. India has yielded a large number of excellent stones, some of which are almost indistinguishable from the ruby; and they have commanded good prices in recent years, owing, perhaps, to the circumstance that American buyers have formed close rings to obtain practically their monopoly. The Indian sapphire is in many respects well suited for blank-shaving blades, being easily ground and re-ground with the black diamond.

The operation of cutting, grinding and

polishing a sapphire recording stylus is considered high art, as certain definite angles have to be preserved, and too acute an angle will give rise to "kicking" in the cleaving of the track of the record. The Bettini type of cylinder recording stylus is the most difficult of all to make satisfactorily, the cup-end assuming a bell-like flange. The object of this provision

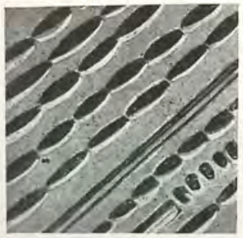


Fig. 9.

Fig. 10.

is to secure a more perfect definition of the minor sounds, especially those of the sibilant order, on blanks of small diameter, viz., the standard size, as well as a greater breadth of tone in a shallow track. The cut by the Bettini stylus exhibits an altogether different appearance to that belonging to the older records made through the medium of the straight cupped stylus. The comparison is at once seen in Figs. 9 and 10, being enlarged facsimiles of fragments of record surfaces made by the two types of styli. Fig. 9 shows the old style; Fig 10 the Bettini type of cut.

As I have already stated, very excellent results in recording may be got by almost any of the recorders commonly sold, if they are accurately set up and carefully adapted for special requirements, with selected diaphragms and first-class sapphires. If the type of recorder known as the gravity type is preferred (and experience has given its support to this preference), it is almost indispensable to employ in

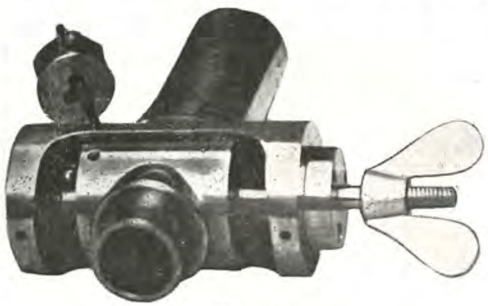


FIG. 11.

connection with it a perfectly sound-tight joint for the best results. The leading manufacturers employ for this purpose what is technically called a trunnion, which is constructed with great accuracy so as to work with the utmost freedom and yet, if it be blown through, no escape of air shall be possible between its movable parts. The only movement which such a device is required to have is simply a vertical, or up-and-down one, for no other purpose than to enable the recorder to automatically rise and

fall with any eccentricities in the revolving blank, commonly called "wobbling." The absence of such a provision in the recorder carriage would, in the event of such contingency, result in the fracture of the recording diaphragm by undue pressure at one part. The form of construction of the trunnion is illustrated in Fig. 11, and it may be connected to the carriage saddle or carrier arm of the machine in any convenient way. The movable portion, to which the recorder socket is to be connected, is delicately balanced between two fine steel centres, while the two surfaces, that of the barrel (which is solid except for the cross-section channel) and the adjacent casement, are ground finally with diamond paste to ensure the most perfect fitment.

It cannot be doubted that records made by the aid of this attachment are far more pure in tone and intense in volume than those made with ordinary connecting sockets, which are generally anything but sound-tight. It is true that a leaky connection will have a tendency to prevent "blast," and I have known some recorders to resort to the practice of perforating the smaller extremity of the recording horn to overcome this difficulty, which has been aptly described as the bugbear of recording. But in these circumstances the tone, as well as the volume, of the record invariably suffer in a corresponding degree, and it is infinitely better to correct "blast" notes by other measures.

It is here convenient to describe what "blast" means, how it is occasioned, and what is best to be done to avoid it. I am confining my observations at present to the cylinder type of record, be it remembered. When a note is sung into the recording horn, the force or impact of which is greater than the capacity of the diaphragm to respond to it within the true acoustical limit, the diaphragm flutters, and in its natural attempt to recover from the undue strain put upon it, it jumps, by sheer reflex activity, the surface of the blank, and consequently breaks what should be a perfectly continuous track. When the reproducing stylus, in reproducing the record, comes in contact with this portion of the record, it produces a harsh and foreign noise in addition to the note, which is anything but pleasant to hear. Not only is the note more or less imperfectly reproduced, but, in addition, the sound occasioned by the concussion of the sapphire against the abrupt edges of the separated undulations—which are represented on the record as a series of holes instead of connected undulations in a constant groove or track—is simultaneously brought out. Fig. 12 represents a portion of a record in which this defect is throughout conspicuous.

It will naturally occur to the average person that the employment of less strength in the emission of the truculent note in question would at once correct the difficulty, which is, to a great extent, true. But one can never be certain just how much or how little strength is wanted to preserve the normal balance between the in-

tensity of the sound and the capacity of the diaphragm. It is always desirable to get as much volume as possible, and this can only be got by comparatively thin, that is to say, sensitive, diaphragms, and it so happens that these are naturally more disposed to cause the trouble referred to than those of greater substance. The use of stout diaphragms will make all "blast" impossible, but records made with these, on the

Fig. 12.

other hand, are invariably thin in tone and lacking in strength.

It is common practice, as a matter of fact, to select the most sensitive diaphragms that can be safely used without giving rise to "blast," for all work. If it is found that the selected diaphragm turns out, on test, to be in every way satisfactory for the particular voice or instrument, except that one or two notes have the "blasty" tendency, then it is usual to employ it, but an admonition is conveyed to the artist either to draw back a short distance from the mouth of the recording horn during the utterance of the robust notes, in order to check their intensity when reaching the diaphragm (this decreasing with the square of the distance), or to hold the notes under greater control, which amounts to the same thing, as far as the mechanical effect is concerned. These dodges are generally effective, but the approximately correct distance to recede from the horn mouth must be gauged by trial, for if the singer remove himself too far, the note (perhaps a display top-note) will be exceptionally "thin" and weak—altogether out of balance with the rest.

There is another matter to consider also. It may happen that though the vigour of the note be restrained very considerably, "blast" may arise notwithstanding, and be due to the molecular reinforcement of the recording horn. I have known certain notes only to cause considerable molecular disturbance in the material of the horn itself, and when a note sympathetic with the fundamental note of the horn is passed through, it is thus augmented, and this is equivalent to what in other circumstances would be too great an intensity in the utterance of the note. It is customary to insulate, or, more correctly speaking, to damp, recording horns to obviate these drawbacks as far as possible, and for that purpose nothing is better than the ordinary electrical insulating tape. It is comparatively inexpensive, and may be procured from any dealer in electrical accessories. It is a sort of cotton fabric coated with a tacky ad-

hesive, and should be firmly wound around the horn, and pressed closely thereto as it is gradually formed as a spiral until it covers the whole exterior. Commencing at the small end, it should be allowed to slightly overlap at the edge in the process of winding, and should be stretched as tightly as may be.

A further method of avoiding "blast" is commonly resorted to by perforating a series of holes in the larger extremity of the recording horn, which allows the vocalist to approach the horn more closely with impunity, the effect of which is to clear the enunciation and secure what is known as the "forward" tone in the reproduction. Sometimes a longer piece of rubber tubing, which is used to connect the horn to the trunnion outlet, will have the effect of checking "blast" by simple absorption, but, as a general rule, the record will suffer in its lack of brightness. In the matter of "blasting," it is invariably the open vowel sounds which give the recorder the most trouble.

In the year 1900 Mr. Edison took out letters patent for an apparatus designed to prevent "blasting" in recording, which was the first attempt to grapple with the difficulty from the mechanical standpoint. The British specification numbered 13,692 of 1900 fully describes the character of the device and the method of its operation. In Fig. 13 the apparatus is shown in section, and its operation is as follows:—

In all ordinary recording appliances the engagement of the stylus with the surface of the blank imposes a slight upward stress on the diaphragm which tends to buckle the same. This, in Mr. Edison's opinion, destroyed the sensitiveness of the diaphragm. "In order to counteract this upward strain," says Mr. Edison, "I prefer to employ a counteracting

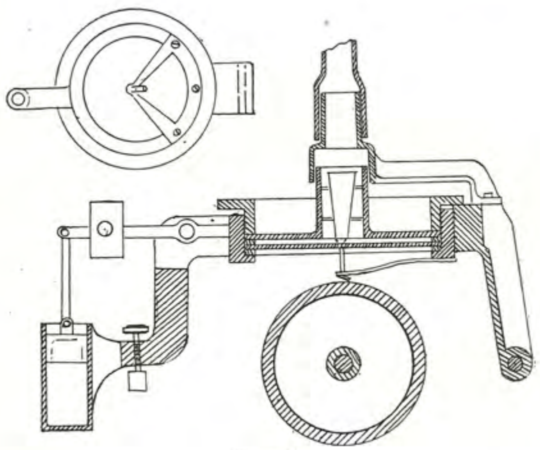


Fig. 13.

weight, which rests upon the diaphragm immediately over the recording device (as shown), and which is guided within the nipple by means of the arms, whereby the weight may partake of a vertical movement. At the bottom of the counteracting weight is an elastic cushion, made preferably of a short section of rubber tubing. By employing an elastic buffer between the diaphragm and the weight, the effect of the

weight will be exerted at all times upon the diaphragm, even though the vibrations are so rapid that the weight cannot respond thereto on account of its inertia."

An alternative scheme in the specification, to the employment of the compensating weight, is the adoption of a tension spring shown in the Figure.

On the publication of Mr. Edison's specification, I lost little time in constructing the apparatus in strict conformity with the text, but am bound to say that my experiments led to no fruitful result. So I pursued investigations in another direction, being convinced, at the same time, that the difficulties to be overcome were susceptible to mechanical treatment. I found by careful experiment that the upward stress ordinarily imposed on the diaphragm by the weight of the recording device, that is, by the contact of the stylus with the blank when the latter revolved at the usual velocity, was really a favourable condition for increasing the sensitivity of the diaphragm. The stress was counteracted dynamically. Firstly, the centrifugal force exerted by the revolving blank tends to reduce the weight of the recorder considerably; in other words, the element of time prevents gravity from exerting its full effect. Secondly, the impact of the revolving blank against the keen edge of the stylus, when set in a holder in the opposite direction to that proposed by Mr. Edison, tends to restore the diaphragm to comparative equilibrium, by the mere effect of the strain of resistance. I found, by actual demonstration, that the method of disposing the stylus arm proposed by Mr. Edison, in which the cutter was pulled rather than pushed through the blank, to be an admirable measure to secure a clean and silent track, but the very means which secured this desirable feature in recording was responsible, at the same time, for depriving the diaphragm of at least half of its vibratory capacity. I found also that the arrangement reduced the disposition of the diaphragm to "blast" under the usual circumstances, but this, of course, merely followed from the fact that the diaphragm itself was checked, as before mentioned.

Every recording practitioner will, I know, agree with me at once in the statement that records which are near the point of "blasting" are invariably more true in *timbre* than records which have no semblance of "blast" about them. This goes to show clearly that there is a very fine borderline which separates the worst defects and the most perfect achievements in the recording art.

Believing the principle of checking a supersensitive diaphragm by a weight to be bad, and believing equally that no advantage could be gained by the employment of a tension spring designed to exert a downward pull upon the diaphragm, it occurred to me that a recorder should be supported upon the blank independently of its contact with the stylus, as far as possible. After numerous experiments, I

found the best form of such a device, as it seemed to me, and procured a patent in 1903 for the same. Its effectiveness may be gathered from the circumstance that most of the record manufacturers adopted it, and have retained it in use; in fact, the principle has been since applied to the disc (needle type) of recorder, which I never contemplated originally. In the latter connection, it has been found to ensure a more uniform track, and to keep the recorder

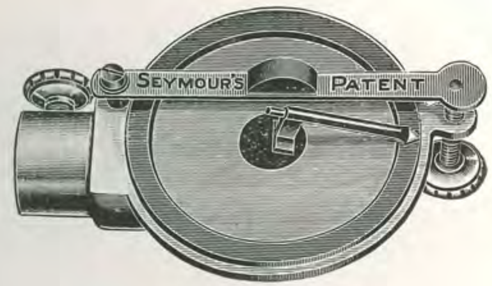


FIG. 14.

steady against extrinsic vibration; so important is this when it is considered that the recording tool for the needle type of disc is otherwise required to be very delicately balanced upon the blank.

The principle of the appliance is at once seen by a reference to Fig. 14. I found that a far more sensitive diaphragm could be employed with safety and without risks of "blast" when this bearing-bridge, as I term it, was used in conjunction with the ordinary type of recorder for cylinders and phono discs. It was common experience that the addition of weight to recorders did something towards preventing "blast," but at the same time the gain in this respect was offset by other disadvantages, arising principally from the stylus cutting too deeply into the blank, causing muffled tones, and almost invariably producing an echo in the reproduction. My appliance was designed merely to overcome these defects, and the adjustable bridge, carrying a bearing piece (a segment of fine cork, graphited, or, preferably, a hemisphere of polished agate) on its underside and in line with the cutting edge of the recording sapphire, the whole spanning the diaphragm, yet without being in contact therewith, enabled the operator to obtain, by means of the adjusting screw, any desired depth of cut in the track. Furthermore, any reasonable amount of weight might be applied to the recorder itself to prevent it from jumping the blank surface without the diaphragm and stylus being in the least strained or otherwise affected.

Notwithstanding these improvements in recording apparatus, it must be distinctly understood that they are of value only to the skilled operator. There is no royal road to recording, and nothing but sheer hard work, close application, and inexhaustible patience will make anyone really proficient in the work. Even the best recording experts are still learning the rudiments of the business, and they are perfectly well aware that finality is yet a long way off. There is no living man who is able to build up a recorder to order and guarantee that it will be suitable for anything but the scrap-heap before it is put to the practical test. The only way at present is to build up a series, and make selections for special work. When the most suitable diaphragm is once obtained, proved only by test, it is usually ear-marked, so to speak, and kept for a particular voice or purpose. I have known (by rare chance) individual or particular recording diaphragms which have been selected for certain qualities of voice to answer equally well for such dissimilar vocal registers as tenor, baritone, and bass. When a diaphragm of such superfine resilience is once secured, it should be prized very highly. It will be worth more than its weight in gold.

The principal work of the recording tool is, as before mentioned, confined to the diaphragm and to the stylus. The next consideration is a good blank, which must be quite smooth, otherwise an indifferent record will be the result, notwithstanding how perfect the recording tool may be. The sapphire is required to cut the blank quite cleanly, and, in scoring the track, the wax should curl off in a long shaving. If the wax is removed from the blank surface in the form of powder, it will be wise to throw out the blank as useless, unless, indeed, the effect can reasonably be ascribed to the low temperature of the recording room, and therefore of the blank, when the remedy will be obvious.

In the selection of glasses for the diaphragm—and glass has not yet been improved upon for general work—only those which emit a clear ring on being gently dropped upon some hard obstacle should be used. Glasses which are devoid of character in themselves will never produce a record of any distinction. I have found that the best diaphragms for recording are those cut from the microscopic cover glasses made by Zeiss to Professor Abbe's formula.

Vocal sounds are infinitely more difficult to produce than the average instrumental type, as the human voice is very complex in character, and does not even present the same conditions to the recorder under all circumstances. As a general rule different vocalists will require different diaphragms, and sometimes the same singer may demand a variation of diaphragm on different occasions, if the acoustic conditions of the room are changed ever so slightly, or the voice itself has undergone some slight change, perhaps only temporarily, but certainly with more or less frequency than is generally supposed to be the case. In order to cope with such subtle difficulties, new diaphragms are constantly called into requisition; or a different focus must be effected, that is to say, a different position must be taken up by the vocalist in relation to the recording horn; and sometimes such a simple circumstance will accomplish a great deal towards the removal of such difficulties.

The vocalist should never make an attempt

to sing into the recording horn in the manner to which his performances on the concert platform have accustomed him. He must firstly recognise that, owing to the limitations of the recording process by present means, he must control the vocal as well as the artistic effort to the end in view, and it is the more or less even tone which has the most telling effect in the production of a good record. The peculiar limitations of the recording diaphragm must be studied, which, if the artist has no mechanical bent—and as it happens that very few have—he can very easily do by paying close attention to the effects of various tests, when reproduced. Such light and shade in artistic expression as may be admitted in the rendition by the singer must be confined within comparatively narrow limits. In the accompaniments, if the pianoforte be employed, the pianist should seldom or very cautiously use the loud, or rather sustaining, pedal of the instrument, which tends to obscure the tone and reduce the definition considerably. The strong *staccato* touch is far more rich in result. The recording horn should be situated obliquely towards the upper register at the back of the piano (the upright type) for the best general pianoforte effects, and should be raised to about the level of the keyboard, and this is to be done, for the better convenience of the vocalist, by supporting the instrument upon a bench or other firm platform some three feet from the floor level. This is the practice in most of the recording rooms. The distance between the mouth of the recording horn and the back of the instrument must be determined by careful experiment and no rule can possibly be laid down, for the reason that the sonorous or recording capacity of a pianoforte is practically an unknown quantity until it has been first tested. It will entirely depend upon the structure and peculiarities of the individual instrument, and the acoustic effectiveness of the recording room. As a rule, the distance found is generally very short, but must be sufficient to permit the vocalist to take up his position between the instrument and recording horn.

Some very excellent effects from the use of the grand piano in vocal accompaniment have been obtained latterly by the experts of the Gramophone Co., in consequence whereof a revival of the piano accompaniment is taking place. Needless to say, the instrument has been specially constructed for the object in view, since the ordinary grand piano has been in such ill-favour with recorders for so many years, owing to the greater difficulty in obtaining as good tonal results as with the conventional upright type. In the use of the grand type, it will not be necessary to support it upon a stand, and the reflecting lid should be raised for the purpose of directing the sound waves into the confines of the recording horn as much as can be. The piano should be placed as near to the horn as conveniently possible.

It is sometimes advisable to use a two-way piece in this connection, which, by means of pieces of short rubber tubing, can be made to connect up two horns, one for the vocalist and the other considerably greater in length, and no larger in the opening, to be suspended down, slantwise, in close proximity to the piano wires. Especially for the robust voice and the female soprano is this device to be commended, and the piano will be heard to greater advantage.

In making orchestral or band records, great attention must be paid to the most advantageous positions which the respective instrumentalists should assume. The general arrangement should be that those instruments which play the melody are not subordinated to the secondary, or those taking part in the counter-melody. Many of the players will need to be raised somewhat from the floor level and benches are provided with one row, and sometimes two rows of seats, for this purpose. Three such benches are usually enough, and are formed up as three sides of a square, the recording horn protruding through the usual partition which forms the fourth side. The aim must be to preserve the correct musical balance or value of the whole combination. An excellent average organisation for military band or concert music will consist of three trombones (first, second, and valve); one tuba; four or six clarionettes; three cornets; two horns; one saxophone or euphonium; one piccolo; and a side drum, if desirable. The drummer usually manipulates the cymbal, bells, and other minor accessory devices for special effects. The piccolo player is also the flautist as occasion requires. The recording horn should be larger than that used for vocals, and should be at least 36 or 42 inches in length, with a flare-opening of, say 18 or 20 inches. The exact dimensions are of little consequence in band work. The best shape is that of the double cone (see Fig. 15)

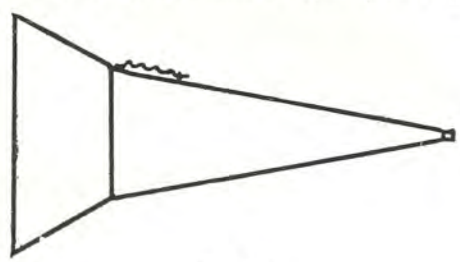


Fig. 15.

It may be made of charcoal iron, stout sheet brass, or blocked tin, each of which metals contribute to the production of a good sonorous tone.

The piccolo should take up a position at the extreme edge of the recording horn mouth, on one side, whilst the drum should be supported in the same position on the other side. The clarionettes should be ranged on either side of the horn, and next in order, being divided equally, and directing the bells of their instruments in the direction of, but at a tangent to, the horn. The clarionettes should be elevated from the floor, some thirty inches or more, by means of two of the benches previously referred to. The tuba is likely to give some trouble on account of its ponderous volume, and it should occupy a chair upon the floor, some twelve feet away from the recording horn, and it may be necessary to direct the bell of the instrument away from the general direction. Much will depend upon the manner in which the instrument is manipulated. Sometimes he has been placed in front of the piccolo, in which case he will be behind the horn, so to speak, and good effects have been secured by this arrangement. A great deal will depend on the cubic area of the recording room. A small room will conduce to the greatest intensification and fulness of tone, even though the performers do not play in full strength. A great deal of volume will be dissipated in a room of large dimensions. Indeed, so much depends upon the particular character of the room employed for the purpose that it is quite necessary to experiment a little to ascertain the most favourable conditions. The euphonium and horns are usually seated on the floor in the central area of the benches, and the three cornets should be assembled in a row at the back, and immediately in front of the trombones, the latter being elevated on the back bench, and some 12 or 14 feet distant from the horn.

I am here giving only approximate positions which the instrumentalists should assume, and the precise ones should be carefully determined by a test record. If the tone, after such a test, is found to be "thin" or weak without any tendency to be "blasty" or predominant in over-tone, then it will be pretty evident that either the diaphragm is too stiff, or if not, that the performers must be brought nearer to the horn. If the tone is still "thin," and "blasting" occurs, a change of diaphragm will be inevitable to correct the defect. The nearer the instrumentalists are to the horn, the more will be the fulness in the tone of the subsequent record. If the general *timbre* is good, but one or more of the instruments have a tendency to "blast" somewhat, the performers should be enjoined to reduce strength, taking care not to unduly disturb the balance of the whole. The recording expert must be, above all things, a man of resource, and if he have an intelligent appreciation of the fitness of things he will quickly discover what to do and what not to do in any emergency, after some little experience.

Experience, to be sure, is the only real teacher in the art of recording. There are so many subtleties to comprehend, so much mechanical finesse to grasp, that no written instructions could ever amount to more than a rough and ready guide. The recording expert is the one man in any record-making establishment who holds the fortunes of the establishment in his hands. Much depends on others, in the allied processes, but they are as nothing in comparison to him. It is pre-eminently *his* work which is judged in the final analysis by the public.

The great paucity of really good records and the plethora of the commonplace is evidence sufficient that really good recorders are extremely few, and are not to be picked up at random. A business such as recording is too young to have developed a large crop of trained and experienced devotees as yet. Experiments in recording are more costly than most people imagine, and this is a serious drawback to the advance of the art. Much has been accomplished by mere accidental discovery, but the inventor is keenly alive to the enormous possibilities which lie latent for want of opportunities in research. There is no valid reason to doubt that absolute realism will one day be reached in the mechanical reproduction of sound. The talking machine is still in its infancy.

. . . . . .

When the "master" cylinder is made and is passed as satisfactory, the next step is to engrave the title of the theme and catalogue number, etc., on the bevelled end of the record, which is done by means of a very complicated machine, costing some fifty pounds. In connection with this machine a large dial, so to speak, with the letters of the alphabet and numerals arranged in a circle near the periphery, is operated in conjunction with an arm, one end of which is a tracker, and the other a very small steel revolving engraving tool. By a motion similar to that of the pantograph, sometimes utilised in drawing for enlarging purposes, the tracker is guided by the hand over the larger face of the dial letters, when the revolving engraving tool, which is brought into contact with the annular extremity of the record upon a conveniently poised mandril, is thereby induced to automatically engrave the desired letters in the wax in much smaller characters. These letters are engraved in this way much more rapidly and accurately than could possibly be the case if attempted by hand; and when a metallic matrix is made from the record, all duplicates are ready furnished with the titling complete. In the final process of finishing, the lettering is made more conspicuous by the filling-in of whiting and size, which is smeared as a paste over the engraving. The superfluous material is afterwards wiped off, but what is left in the recesses of the letters remains, being below the surface.

CHAPTER V.

THE TIMING OF THE RECORD.

The average song or orchestral selection must necessarily be abridged or cut down to accommodate the limited capacity of the blank, which commercial considerations have determined it shall assume. An attempt was made, in the past, to increase the standard length of cylinder records to six inches, but without much success. Once a standard, however wrong, has been set, it is indeed difficult to displace it on account of the large number of reproducing machines already sold to the public to which radical innovations are not easily applicable. There are always numerous enthusiasts who would have no hesitation whatever to turn their old machines into "scrap," and who would willingly acquire the latest improvements. But these are never sufficiently numerous to consider from a commercial point of view. The expense of manufacturing new types of machine and records is great, for it is only their production in large quantities which enables them to be made at possible prices at a profit. Every shrewd manufacturer, therefore, who has, generally speaking, but a secondary interest in the purely artistic and progressive aspect of the talking machine, will naturally endeavour to conform to the standard requirements as far as possible in the introduction of any improvements he may feel disposed to make. That is one of the strongest reasons why progress is so slow.

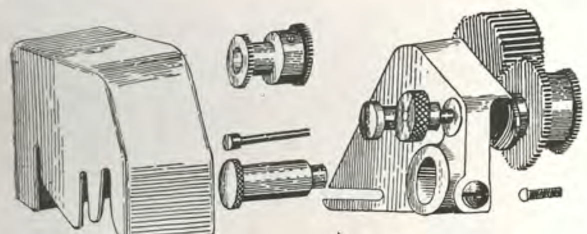
An excellent scheme for extending the length or playing capacity of records was one patented (since lapsed) by Mr. Bawtree in 1905 (specification, G.B. No. 4680). It consists in the record being made in the usual way upon a cylinder of extraordinary diameter, say three feet, after which it might be electrotyped in the usual way for the production of a metallic negative which, in turn, might furnish any reasonable number of copies in a flexible material such as comparatively thin celluloid. The *modus operandi* in the manufacture of celluloid records will be explained in detail in a subsequent chapter. The huge cylinder, when pressed in celluloid is removed from the matrix and instead of being mounted upon a solid core to adapt to the ordinary mandrils of the standard reproducing machines, it is reproduced by being placed in a manner analogous to that of a machinery belt over two pulleys or small cylindrical mandrils, and is run in that wise, the reproducing mechanism being adapted to contact with the portion of the record on the upper mandril, and having the usual traverse motion for the purpose of following the track spiral. The only practical difficulty about the scheme is that the record band would have to be adjusted to a considerable tension to avoid possibility of slipping and also to produce firmness of tone. To

secure these results by such means would require a driving mechanism of powerful proportions, and it is indeed doubtful if a spring motor, however powerfully built, would be equal to the task imposed upon it. The great superiority of the system, however, lay in the circumstance that records could be made of almost any duration, in playing capacity, by the increase of length or of diameter, or both. The original recording machine, and the original record would, of course, be somewhat clumsy affairs, but as the duplicates in celluloid would be endless bands capable of being folded up with some compactness, this circumstance would not affect the commercial side to anything like the same extent.

In the early days of the phonograph, the records were made to reproduce about double the length of the standard 100-thread-to-the-inch records. These were the progenitors of the latter-day Amberols. But in those days they were "masters" in comparatively soft wax, and the moulding process had not been brought into requisition, through which harder compositions in the duplicates could be secured. Probably this reason alone sufficed to cause their early demise, for those who can remember will confess that much superfine tone was secured in these early specimens. The 100-to-the-inch track soon became the practical method, and in conjunction with the vacuous-deposit system of electrotyping introduced by Mr. Edison, the best examples of these have never yet been surpassed for tonal beauty and fine definition. But the demand having arisen for a record of greater length, Mr. Edison was induced to re-introduce the 200-thread record, which he christened as the "Amberol." Considered in its commercial aspect, and taking means and end into account, I regard this innovation, together with the accessory differential gears to reproduce them upon the old standard machines, as a piece of high mechanical genius. But, artistically, these records have never succeeded in the full sense of the term. What was gained in tone-colour was lost in tone-realism. The greater volume of this latter-day product over the original white wax masters of this variety was produced by superior recording processes, and by being moulded in denser material. Nevertheless, it is a truism that in Nature everything is co-related; it could scarcely be expected that a record of the same dimensions, and possessing double the length in playing capacity, could retain more than half of its tonal effects; and it is something after all that a small cylinder, scarcely more than two inches in diameter, and less than four inches in length, has been made to play for an average of four minutes, instead of two, by means of a small variation in the old standard reproducing mechanism. This mechanical attachment enables the mandril to revolve at the same rate as heretofore, viz., 160 revolutions per minute (the assumed standard velocity) while retarding the lateral

travel of the carrier-arm and reproducer to half of its original speed. By pushing a small knob attached to one of the gear-wheels, the old gear of 100 to the inch traverse is again effected, if desired, and instantaneously. A much smaller stylus must, of course, be employed, since the track is so much finer than that of the older standard.

The foregoing description of the differential gear employed may be supplemented by the figure below, which represents a group of the parts which make it up, ready to be assembled



THE AMBEROL ATTACHMENT.—FIG. 16.

upon an Edison "Standard" phonograph. This attachment may be easily applied by any ordinary mechanic, in less than half-an-hour, by following the printed instructions which accompany the sets as they are sent out by the manufacturers.

The "Amberol," or 200-thread record, was originally moulded in a wax substance, of considerable density, on account of the greater risks of injury to so fine a track with a correspondingly finer stylus. Shortly after its appearance upon the English market, and having made some close observations with reference to its friability, and certainly long before the "Blue" Amberol appeared at all, I communicated my impressions to the *Talking Machine News*, of January, 1910, and boldly suggested that the Amberol record in any kind of wax material was not a practical proposition; and, having in view my previous experiments with celluloid cylinder records, I declared that only by the adoption of celluloid or similar cellulose material could the technical, as well as the commercial, success of the "Amberol" idea be ensured. I stated that I had already produced samples of 200-thread cylinders in celluloid, and that, in addition to the greater durability of the record itself, a superior volume and quality of tone was also obtained. I took the commercial wax Amberol record as I found it, and, after treating its surface to render it electrically conductive, immersed it in the sulphate of copper bath connected to a dynamo, and grew an electrotype upon it. This, of course, constituted the mould for the celluloid duplicate. I was thereby enabled to make an exact comparison on the questions of durability, volume and fidelity of tone, in actual reproduction, inasmuch as it were easy to obtain any number of wax copies for this purpose from the market stock. It is interesting to notice that Mr. Edison, some two years later, saw the

matter in the same light, and thereafter superseded the wax Amberol by the "Blue" (celluloid) Amberol record, which has now achieved a far greater degree of popularity, as well as a higher standard of technical excellence.

CHAPTER VI.

THE MAKING OF DISC RECORDS.

Much of the instruction in the foregoing chapters having reference to the recording of cylinders will be equally applicable to the making of discs. The appliances will be different, as a matter of course. A machine for recording the latter will require to be constructed on heavier lines in consequence of having to do heavier work. There are numerous types of disc-recording machines in use, all being designed to accomplish the same end. Some are extremely simple in construction, while others are very complicated and convenient. Fig. 17 represents one of the early types, designed by Fitch, showing the usual gravity motor attached, and also the recording trunnion and vertical disc recorder in position. It will be seen at a glance that the motor, actuating the driving belt attached to a pulley on the underside of the turntable, revolves the latter; and by means of a smaller pulley with cord attached the feed mechanism is operated simultaneously. The recording horn is connected to the inlet tube of the trunnion with the aid of a short length of rubber tube somewhat flexible, to permit of free motion of the slide.

The whole being super-imposed upon a rail with runners more readily allows the hand to guide the machine along steadily when making a record so that the horn focus is approximately constant, which is somewhat important when recording instrumental combinations.

It is very desirable that the table of the disc

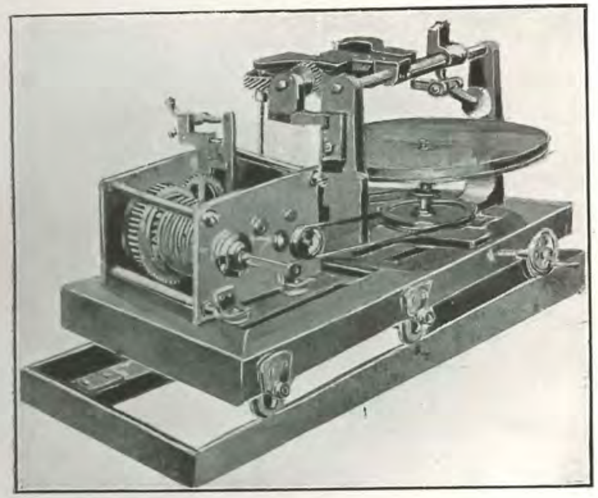


FIG. 17.

recording machine should revolve with great steadiness and accuracy; and the spindle which carries it should be fairly stout and rigid. I have seen some of these spindles an inch thick, but there is nothing to be gained in excessive rigidity, as correspondingly heavy bearings are in that case likewise needed, which act to call into play much undesirable friction. The two bearings may, however, be arranged as ball-bearings, or the under bearing may be disposed as a "centre," or may be cupped to take a small ball set in a corresponding cup at the base. I am not disposed to favour the use of ball-bearings, however, for this purpose, as they are rarely true

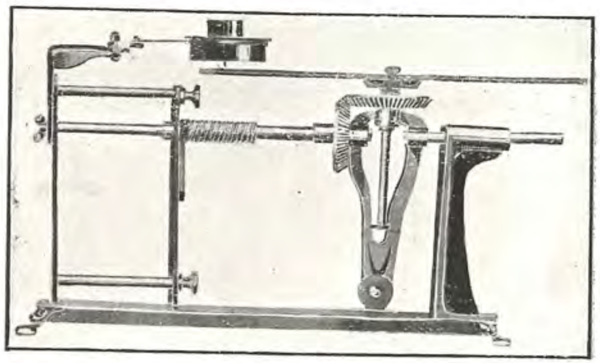


FIG. 18.

in the running, and merely favour the reduction of friction. The cone bearing is by far the best principle, but will require greater power to drive. And yet it is imperative that a recording machine shall be designed to be driven with the smallest actuating source of energy compatible with the object, on account of the difficulty in correctly governing the regularity in the motion of heavy apparatus, and when so

much depends on perfectly regular motion from the recording and acoustical point of view.

The more recent types of recording machine have been designed to perform the traverse movement by the table itself, recording apparatus and horn being quite stationary. This has been accomplished by a different disposition of the feed device, and a revolving feed-screw working freely with a fixed feed-nut in the frame. A machine operated on these lines was patented in 1900, an illustration of which may be seen by referring to Fig. 18. The mechanism is somewhat analogous to that of the original phonograph, and of Scott's "Phonautograph." The only advantage gained by an arrangement of this kind is that the recording horn is constantly at one focus to the recording sounds, but this is, nevertheless, one of no small importance. A more perfectly designed machine on the same lines is that of Dixon, shown in Fig. 19. The whole of the framework carrying the feed screw and underneath gears slides with the table on a shaft at the top and against a straight edge at the base. The feed-nut is held by a spring clamped to a solid standard which is fixed to the base. The recorder-holding attachment (adjustable) over the table can be set in any desired position to accommodate different diameters of blanks. It will be seen, also, that vibration is reduced to a minimum at the essential point by the turntable being revolved by means of a metal-plate encased rubber bevel wheel held at a moderate tension to a bevelled projection on the underside of the table. The slide-rod carrying the rubber bevelled wheel is slotted, and passes freely through the driving pulley, at the extreme left-hand of the illustration, which merely revolves but has no side movement whatever. The feed-screw is operated by a helical which is part of the table spindle. The whole is a very perfectly

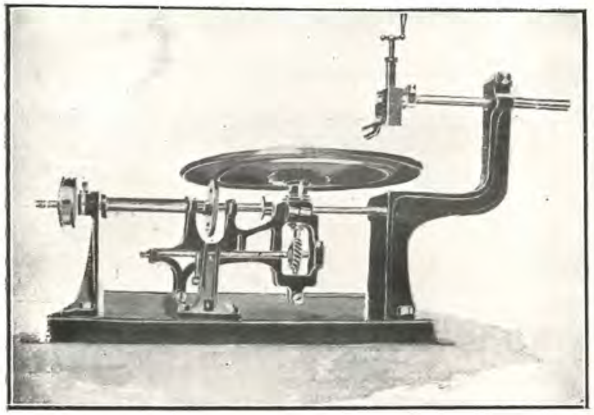


FIG. 19.

assembled piece of mechanism, but it has one drawback: it requires a strong actuating motor, which must be connected with a belt. The danger of slipping, under considerable resistance, is real, with results, in the acoustical connection, which might prove appalling.

I have referred to the advantage which the

machine with the lateral traverse of the turn-table is supposed to possess over that with the simple rotating table with travelling recorder, which is that the acoustic focus is always constant, other things equal. The object of this arrangement is to preserve an uniform quality of tone in the record. To a very great extent, however, this desirable result may be reached by other and simpler means; and the use of a metal tubular bend, or rectangular conduit, connected with the trunnion and the recording horn by a short length of rubber tube—so that the horn, lengthwise, is parallel with the feed screw—will certainly vary the distance slightly of the horn mouth, but will, nevertheless, keep it constantly in the same relative angular position. In such circumstances, it will be desirable to suspend the recording horn in such a manner with a travelling pulley upon a taut wire, so that any resistance to the drag of the horn may be minimised as far as its effect upon the feed-screw is concerned.

The most satisfactory type of motor for actuating the disc recording machine is the weight, or gravity, type, analogous to the motors employed by turret-clock manufacturers. If properly constructed, these motors are steady and reliable. In the early days, the electric motor was resorted to, but, owing to its uncertainty in governing, it was soon abandoned in favour of the weight motor. The drum, or power shaft—around which is wound a fine steel cable—is sometimes turned out of hard wood, having metal spindle and supports, and sometimes it is all constructed out of metal. The cable is secured at one end of the drum, which is also fitted with a pawl and ratchet; and, by means of a crank, it is wound around the drum in successive layers, after the fashion of a windlass, the other end of the cable having attached to it a heavy weight. A train of toothed wheels engages with the drum spindle, furnished with governing apparatus, much after the manner in which a similar wheel-train is connected with the clock-spring spindle of ordinary gramophone motors, although heavier in construction. The gravity motor is generally bolted down securely to a firm bench, the cable running upwardly (for convenience) and over a pulley, or series of pulleys, attached to the joists of the floor above, or rafters of the roof, as the case may be, to enable the heavy weight (generally about 1 cwt.) to have an ample drop, that is to say, to permit of a sufficient number of revolutions by the drum to actuate the driving pulley for a sufficient length of time to carry at least one record through without the necessity to rewind. An illustration of one of these motors, adapted to actuate a recording machine by means of a belt is given in Fig. 20, which will enable the reader to see at a glance how the power is obtained and the speed of rotation accelerated.

The obvious superiority of the weight motor lies in the fact that the source of power is even and constant. Its construction, moreover, is

extremely simple, not likely to easily get out of order. Its only disadvantage is its clumsiness, and the necessity for a considerable drop length, as far as the weight movement is concerned. The cable may be arranged, if desired, to travel in a straight line from the drum through a hole in the wall of the recording-room, or out of a window, if the recording-

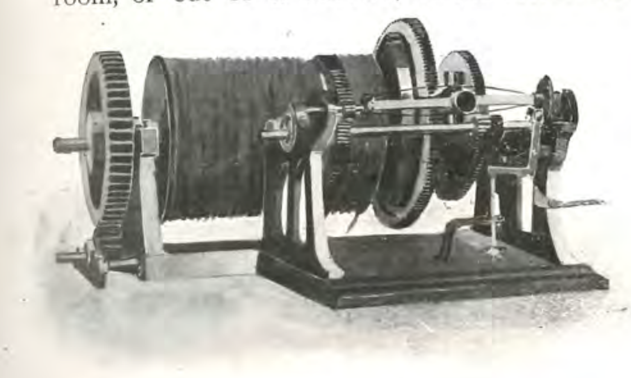


FIG. 20.

room is situated above the ground floor; and the weight may be adjusted to drop, by means of a pulley wheel, below the floor elevation. Or a series of pulleys may be arranged to economise the downward drop, in the well-known way, but this scheme would entail the necessity to employ a heavier weight, in order to compensate the increased resistance of the pulleys.

To those who, for a variety of reasons, would prefer to adopt the electric motor to operate the recording machine, I would draw attention to a very excellent device invented by Mr. Ezekiel, which certainly does much, if not all, to correct the occasional breaks in the electric current which have been so great a source of annoyance to the operator in the past. It is exceedingly convenient to press a button, or turn a switch, to put the recording machine in motion; the electric motor, connected to the lighting circuit, is exceedingly compact, besides doing away with the necessity of winding. Its uncertainty in governing is its only drawback. In what manner does Mr. Ezekiel overcome this inherent defect of the system? By attaching a knuckle joint to the armature spindle, connecting with a flexible cable of short length, the other end being attached to the governor spindle of a train of wheels ending with the turn-table spindle. The high velocity of the motor spindle is thereby geared down to the required velocity, and any "twitch" in the current is absorbed by the flexible cable through the regular momentum of the turn-table. He has assured me that the arrangement is an unqualified success, and I have no reason to doubt it. But I have never had occasion to test the principle for myself.

CHAPTER VII.

DISC RECORDING APPARATUS.

Having succeeded in getting the recording machine set up, with its attached motor—if the whole be not self-contained—in good running order, the first important thing to do will be to regulate the velocity of the turntable to the generally accepted standard of 80 revolutions to the minute. This speed is, of course, arbitrary, and need not necessarily be followed. In fact, there are many technical reasons why such a standard should be set at naught. All that can be said for it is that it is a convenient compromise, and its observance does not entail upon the public the need to continually change the turntable speed of their reproducing machines, which would certainly be requisite if the alternative of variable speeds were adopted.

This relation of speed in the motion of the recording blank is well understood, its object being to continuously furnish new ground for the recording stylus to cut the spiral track, and to simultaneously register the sound-wave markings therein corresponding to the vibrations of the particular sounds it is desired to record. Now, it is incontestably proved that the different sounds which come within the scope of the average or normal human aural function are characterised by very wide differences in vibratory frequency. The deepest bass sound audible is produced by 32 vibrations in a second; the sharpest treble sound by something like 15,000 in the same time.* It will be obvious at once that the higher vocal registers require a considerably higher speed in the moving blank than the lower registers, if anything like a true value is to be given to each; that is, if the normal dimension of the sonorous wave in each class is to be accurately registered. For the lower and middle registers, the standard speed will suffice very well, but it is altogether inadequate for the soprano pitch, the more so when we take into account the reproducing methods in vogue. It has not occurred to the minds of recording experts, presumably, that their significant failure to record the vigorous soprano voice, as effectively, let us say, as they record the full baritone types, is due, pre-eminently, to this fundamental if simple question of turntable velocity.

Let us now turn our attention to the disc wax blank. In a previous chapter I have referred to its composition, and its subsequent treatment by way of preparation for the recording process. Its beautifully smooth surface is all

* The production of a note of any higher octave is occasioned by twice the number of vibrations per second to that of the corresponding note in the octave lower. *Ergo*, if C on the piano is produced by 258 vibrations per second, then the octave, or eighth note higher, is produced by 516 vibrations, and so on.

that can be desired, we will assume, but it will still be necessary to warm the blank prior to recording, in order to ensure clean cutting by the recording stylus and to reduce unnecessary friction, and consequently, surface noise, in the final reproduction. The most convenient form of oven for this purpose will be a wooden cabinet, zinc or asbestos lined, with several shelves made of lattice-work, or rods about one inch apart, so that the heat may be transferred, from its source at the base of the cupboard, upwardly and penetrate the mass of the blanks to be so treated. Mere surface warming is utterly insufficient, as cooling would be too rapid and uneven when placed upon the machine, and during the recording process. It is also customary to maintain a fairly high temperature in the recording room, not only to assist in keeping the blanks in condition, but to promote the acoustic properties of the room itself. A little experience will soon teach the recording operator just what degree of warmth the blank will require for best results, and some compositions will require to be warmer than others, according to their density.

It should not be heated excessively, of course, and perhaps the best general test to which the blank, prior to use, should be submitted, is that the cut from the recording stylus shall be clean, comparatively silent, and shall throw off the wax so cut away in a long thin thread, which can be easily blown away by the breath.

The best source of heat for the warming

chamber referred to is the electric radiator, as gas jets invariably cause condensation, and the beautifully shaved blank surfaces may be thereby spoiled. Steam pipes may be employed, if desired, but only a moderate heat must be allowed to be given off, so that the warming is very gradually accomplished. The usual plan is to keep the blanks in the chamber for two or three hours before use. A heat too intense will often split the blanks as well as distort their shape; and I have found it an excellent plan to lay the blanks, with their faces upwards, upon pieces of plate glass, on top of the racks, so that their level surfaces may be kept intact, and all "sagging" of the material, by the effect of gravity, be obviated.

The short stud which projects from the upper side and centre of the recording machine turntable will serve to keep the blank in the correct position. Generally speaking, blanks are prepared with a central hole of 7 millimètres diameter, but a more recent method is to furnish the blanks with a recess of the same diameter on the underside, about three-quarters of an inch in depth, which engages with the turntable stud, and leaves a perfectly plain surface above. The object of this arrangement is to ensure a more exact "centre" mark for the subsequent boring of the central hole in the metallic matrix. Sufficient now to say that before the wax record is removed from the recording machine, the exact centre should be found by an adjustable style, and a minute

ring inscribed automatically by a revolution of the turntable by hand.

Usually, the dead weight of the blank will be sufficient to hold it down snug to the turntable, and to prevent creeping during the recording, but for safety, two, three, or four clamps may be attached to the edge of the table with adjusting screws to press against the outer wall of the blank. Either before this

SINUOUS TRACK.

UNDULATORY TRACK.

FIG. 21.

operation, or at the time of trueing up the blank in its earlier stages, a triangularly shaped tool should be made to cut a small groove, about one-eighth of an inch in depth, mid-way on the outer wall of the blank; because, at a later stage, when subjecting the record to the electrolytic bath for securing a matrix (for the duplication of records for the market), it must be provided with some means by which it can be vertically suspended therein without any contact with the face of the record. The afore-mentioned groove will permit a length of copper wire to be bound around the edge of the record, which, at the junction of the ends of the wire, should be looped for hanging on the bath rods in the circuit. I may mention that a later method avoids this necessity by supporting the record in a frame or holder made of vulcanite, which is non-conductive, the current being carried to the outer edge of the record by a fine conducting wire of copper. Sometimes the electrotype is expedited by an additional conductive wire to the centre of the record, the growth taking place from the two points simultaneously.

It is next in order to explain the construction of the recording tool for discs. For the recording of discs having the undulatory track, known as phonograph cut discs, the same type of recorder is used as in the making of cylinder records. These have already been explained and illustrated in an earlier chapter, and need no further description. The recording machine must be furnished with a satisfactory sound-tight joint with a vertical motion only to rise and fall with every slight variation in the blank, if any should take place. What is called a trunnion is the best form of this indispensable attachment, and an illustration of the same has already appeared in the section referring to cylinder work. In the case of discs, however, the bore should be

somewhat larger than that employed in the recording of cylinders. The tubular extension of the trunnion which connects with the recording horn by means of a short length of rubber tubing, may be as large as one inch in diameter, tapering down inside to about five-eighths of an inch at the orifice in the barrel which effects a junction with the recording tool.

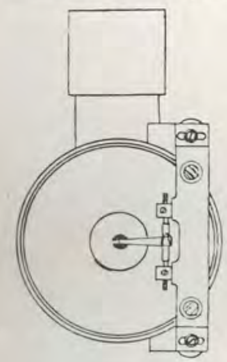


FIG. 22.

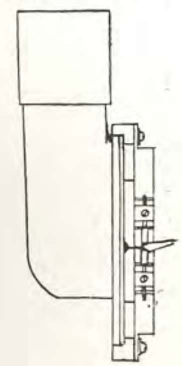


FIG. 23.

A front and side elevation view of a recorder designed for discs having a sinuous track, known as "needle" discs, is given in Figs. 22 and 23. Some makers prefer that the socket of the recorder be provided with a set-screw to firmly fasten it to the trunnion. Others prefer to bore the conduit of the trunnion barrel taperwise, and provide the recorder end with a corresponding male taper on the outside for simple insertion of the latter into the former. This arrangement is undoubtedly best, as allowing no side play, but it requires to be very accurately made—indeed, the two surfaces must be carefully ground to a perfect fit in order to avoid any possibility of slipping. The use of a set screw and collar to the recorder is possibly more certain, but the tightening of the screw in practice generally throws the recorder slightly out of alignment, which is to be avoided for several reasons.

It will be seen by a glance at the arrangement of the recording tool in the first figure that the plane of the diaphragm will be parallel to the plane of the blank when in action. The zig-zag character of the vibratory motions on the wax by the stylus is produced by the small lever movement which is supported upon the bridge spanning the diaphragm. The movement itself is connected at one end by a piece of fine steel wire to the centre of the diaphragm, fastened thereto by a tiny blob of shellac, wax, or seccotine. The other arm of the rectangular lever is furnished with a triangularly pointed sapphire stylus, with a highly polished and keen cutting edge. It must on no account be made heavily to favour sonorous absorption, yet it is required to be made strongly and be possessed of considerable rigidity. The lever is usually made of steel, the fulcrum being a pair of minute centres, which are adjustable in the most delicate degree. These tools may cost anything from £1

each to make up, on account of the care required to be exercised in their mounting. The sapphire styli cost about 2s. 6d. each at first hand.

A point to which particular attention should be directed is the correct weight which the recorder should impose on the blank surface. For needle disc records, having a track of virtually constant depth, it is not necessary to cut into the surface very much, since the track in the finished record is only a guide for the trailing needle attached to the reproducing soundbox. The recorder being of larger dimensions than of the type used for cylinder work, its weight is correspondingly more, and means must be resorted to for releasing most of this dead weight. The trunnion should be furnished with a rod extension from the barrel, in the opposite direction to that of the recorder, with a sliding block of metal, capable of being fixed at any requisite position on the rod, by means of a set-screw. The required equilibrium can thereby be secured, for the recorder stylus must pass very lightly over the blank surface. The weight required is very little; and if too much is given to the recorder, not only will the track be excessively deepened but the freedom of the diaphragm will be impaired, and the stylus will kick and fracture the track and prevent any satisfactory record being made.

A suitable size of diaphragm for the recording of band or orchestral selections will be found to be from $1\frac{3}{4}$ to 2 inches in diameter.

For vocal work, the size may more advantageously be from $1\frac{1}{2}$ to $1\frac{3}{4}$ inches. The general directions as to placing the performers before the recording horn, which were given in a previous chapter having reference to the recording of cylinders, may be followed with very slight variation. There is a smaller disposition to "blast" in the recording of discs, owing to the

FIG. 24.—DISC RECORDER.

lateral motion of the stylus, but the over-vibration of the diaphragm may just as easily take place, if too great a force be directed thereat, and which will result in a corresponding defect in the record in which it occurs.

Another type of disc recorder, and one which is finding increased favour with operators, is the vertical, being constructed so that its diaphragm and stylus bar assume a perpendicular position (see Fig 24). By its use, both fuller

and stronger tones may be secured. In addition, the stylus motion more nearly approximates that of the reproducing soundbox, for which reason a superior quality of tone is preserved. There are, of course, several schemes of construction, the one illustrated showing the stylus bar lever held by a small blob of beeswax to the fulcrum bridge. The shorter the lever arms on the under side of the fulcrum the smaller will be the tendency of an over-vibrated diaphragm to stamp its deleterious effects upon the record, but the volume strength will be correspondingly reduced. The usual practice in the recording rooms is to employ recorders of this type with a metal bar across the diaphragm (but out of contact with it) so that the fulcrum may be placed about midway between the centre of the diaphragm and the extremity of the cutting stylus. The waves recorded under these circumstances will be practically of the same amplification as that of the diaphragm itself. It should be pointed out also, that the attachment by a small piece of wax of the stylus bar to the fulcrum bridge as herein shown, is merely a simple way of constructing a tool of this character, and is not extensively adopted on account of the readiness with which the stylus may be accidentally detached. The most common method is to mount the stylus, fitted with a small block, between two fine steel centres, set in small studs, and which are delicately adjustable, inasmuch as there must neither be binding nor slackness in the bar itself. It should be just free to move in response to the motions of the vibrating diaphragm, which has a very limited extent of motion indeed. The bass and baritone, and even tenor and female contralto voices, are usually recorded with ease (given a suitable diaphragm) with such a diaphragm with a prehinged stylus bar; but on account of the greater periodicity of the soprano, it is preferable to employ a "check action" or tension springs to keep the stylus under some amount of control and to facilitate rapidity of recovery. A change of tension, by adjustment, will frequently render a change of diaphragm unnecessary when dealing with a troublesome voice, and even when dealing with different subjects. The tone is also more solid, more firm and clean.

The greatest care must be observed in fixing the diaphragm to the "shell" of the recorder. It should be lain perfectly flat on a thin rubber gasket of the same diameter, and, being gently held in position by pressure of the thumb upon the diaphragm itself, should be fixed by means of a heated solution of bees-wax and resin in equal parts, which, when set, will retain a fair measure of "tack" or flexibility. Diaphragms should never be affixed by such hard-drying adhesives as seccotine, or other fish glues, which will enormously reduce the vibrating capacity thereof. If the bees-wax and resin mixture be made in a small ladle, it can easily be heated to the fluid state by means of a small spirit-lamp, and a small spoonlike tool, made from

a short length of brass tube, about one-eighth of an inch in diameter, filed at one end to somewhat resemble a pen nib, will be useful to pick up the fluid and run it around the edge of the diaphragm and gasket. The wax need not overlap the diaphragm at all.

Another variation of the vertical recorder consists in the stylus-bar being made with a fine steel cross-bar rigidly attached, one end of which acts as a centre to engage with a corresponding female stud, the other being turned upwardly and flattened as a knife edge to insert into a corresponding slot in the opposite stud. The bar is then held taut by a silken cord, attached to an adjustable terminal, and disposed so as to pull in the direction of the centre, in order to keep the bar perfectly rigid, without any interruption of its required backward and forward motion. There is really nothing to recommend this particular method of mounting that I have, by experience, been able to discover.

In setting the cutting stylus into the end of the stylus-bar—which should be bored partly up for that purpose—care must be taken to get it parallel with the diaphragm, as well as the cutting edge at a right angle thereto. The best medium for mounting this is shellac, heated to the necessary degree. The usual styli employed for needle discs are manufactured from sapphire, on account of its density and susceptibility to a high polish for clean cutting of the blank. They are triangularly pointed in order that the cut-track shall assume a V form in cross section, for the superior advantage in the subsequent duplication in the presses, and also for the better tracking of the reproducing needle.

CHAPTER VIII.

MAKING A TEST RECORD.

Now that we have the recording machine in order, the blank warmed, and the recorder attached to the trunnion, we will next proceed, step by step, to make what is called a "test." This is the necessary preliminary to making an actual record, and has as its object the discovery of the suitability of the particular voice it is desired to record to the diaphragm of the recording tool. It is a peculiar experience that certain kinds or qualities of voice record much more easily than other kinds, and sometimes it is only with the utmost difficulty, and by the expenditure of extraordinary patience, that a certain type of voice can be recorded at all. This is one of the mysteries of mysteries, which readily explains why there is, as yet, no technique in recording. In nine cases out of ten the results achieved are haphazard and accidental, although experience and close observation assist very materially in securing conditions as favourable as possible.

When a few bars of a song have been sung by the artiste into the recording horn, it will be necessary to reproduce the same in order to judge the result reached. For this purpose a feather-weight reproducer, with a very sensitive diaphragm, and having a swivelled side motion, must be employed, which should be attached to the recording trunnion, and brought over to the commencement of the track, so that it can be carried by the feed screw over the whole area of the recorded section. The result will be comparatively feeble in any case, but experience will soon teach what the result will be when the record is pressed in the hard composition known to the public, and when a heavier and more firmly tensioned soundbox is requisitioned in its reproduction, aided by the conventional amplifying horn. It need scarcely be remarked that the passage of an ordinary soundbox, with a steel needle as a stylus, over the wax record, would not only completely destroy it by a single reproduction, but would at the same time render it extremely difficult to ascertain its value or otherwise, inasmuch as the destruction of the sinuous sound waves would take place coincidently with the reproduction.

Recording experts are obliged to be very dexterous in the use of powerful magnifying glasses, as defective recording, as well as successful recording, can in a great measure be seen by a comparative study of sinuous markings. Difficult as recording undoubtedly is, requiring the utmost mechanical aptitude if scientifically approached, requiring in any circumstances the observance of the greatest vigilance and judgment in acoustical phenomena; working comparatively in the dark by reason of inadequate demonstration of results from the

wax, yet it is true that the trained expert is able to estimate pretty accurately the final result by the ordinary process of deduction. It sometimes happens, however, that the slightest miscalculation or oversight will make just the enormous difference in the final result between a brilliant piece of work and the most absolute failure. It is for this reason that the average cost of producing first-rate disc records is very great.

If the recording operator is fully satisfied, after one or more tests, variously modified according to circumstances, he puts aside the test blank and takes a new one for the final effort. This last is made with all due regard to what has been discovered by the test, and when the record is completed, it is merely subjected to microscopic examination for mechanical faults, but is never reproduced so as to suffer the least mechanical injury by that operation. It is put carefully aside, if found to be quite free of technical defects, ready to be handed over to the electrotyper, whose business it is to make a metallic negative of the record, from which duplicates can be pressed, the details of which processes will be explained in subsequent chapters.

It will be found, when the recording of the blank is going on, that the wax removed by the cutting stylus will form as fine threads, and will have a tendency to cling about the stylus point. This should be avoided as far as possible as it may clog the path between the uncut portion of the blank and the stylus, and prevent a nice, clean engraving. It may be blown away gently by the breath, but foot-bellows are commonly employed to which is connected a length of flexible rubber tubing with a metallic nozzle at its terminal. The nozzle is then directed to the spot to be cleared as frequently as necessary. Others employ a small centrifugal fan, with suitable conduits, one of which is attached just behind the recording stylus, the other leading to a box or other receptacle, and into which the shavings of wax are automatically conveyed by the principle of suction.

I had occasion to mention, in the chapter dealing with the preparation of disc blanks, that it was sometimes the practice to drill a central recess on the underside of the blank to engage the recording machine turntable stud, instead of boring a hole completely through the blank. The object of this is to leave the blank face intact, so that, before the blank is removed from the turntable after being recorded, the exact centre of the record may easily be found by an adjustable stile and which may be transferred to the electrotype as a guide to the mechanic who is subsequently entrusted to true up the same, and to bore the usual central hole. It is highly desirable that this hole shall be quite central, or the record will not be constant in tone pitch, and the slightest eccentricity in its rotation will cause an otherwise excellent record to be unpleasantly reproduced.

In making disc records with the phonograph track, that is to say, with the undulatory as contradistinguished from the sinuous track, the former have every advantage in the way of testing results, inasmuch as a ball-head sapphire may be used in the reproducing, which engages with a track of broader dimensions; and which is U shaped in cross section. Such records may be tested far more perfectly by means of a light floating reproducer or sound-box, with a minimum of injury. Moreover, a greater volume of sound can be obtained from the wax than can possibly be secured from the sinuous track in the wax. The strenuous tones with which we are familiar in connection with sinuous, or needle, discs are due almost entirely to the hard composition of which these discs are subsequently pressed, which offers extraordinary resistance to the sound-box stylus during reproduction, and by which a correspondingly greater thrust is directed to the diaphragm—through the impetus of the sinuous wave-marking.

It is here convenient to make a few observations upon the respective qualities or merits of "needle" and "phono-cut" discs. Technically, the latter is superior to the former, principally for the reason that a smaller loss of the finer essentials of tone takes place, in that the recording diaphragm is required to be closely in juxtaposition to the blank surface, the recording stylus, fixed directly to the diaphragm centre, alone intervening. Other things being equal, this is, both theoretically and practically, an enormous advantage as compared with the necessary method of recording "needle" discs, viz., by means of a lever motion, which invariably produces tone-reverberation as its essential characteristic. Then again phono-cut discs are practically unwearable, and the reproducing stylus need not be repeatedly renewed as is necessary with "needle" discs, which is at least a desirable matter. And, notwithstanding the larger area of contact by the sphere-head stylus with the record, the surface noises coincident with such friction, is not more pronounced than that in connection with "needle" discs; but less so, as Mr. Edison's latest examples of phonograph disc, reproduced with a polished diamond stylus, have clearly shown.

It is difficult for the layman to form a correct conclusion upon the superiority or otherwise of these respective types of disc record, because, apart from the difference in the stylus motions in the recording, other conditions are seldom equal. If the recording diaphragm used by either system be not checked by methods employed to connect the stylus therewith, the vibratory motions of both must necessarily be similar in character; and whether the wave-markings are undulatory or sinuous matters very little. A side elevation view of the undulatory track would present the same general features manifested by a plan view of the sinuous track. The important thing is to make exact comparisons between the respective mark-

ings following from the same recorded sounds. In general, more force is required to be expended in agitating a needle-disc recording stylus, notwithstanding the decreased resistance of the blank—the track being small and of approximately even depth—than in agitating a phono-cut recording stylus, which is compelled to cleave, by varying degrees, into the body or substance of the blank. This should be sufficient to show which is the more sensitive means to the end in view.

Reverting to the general *modus operandi* of recording, the foregoing should be borne in mind in selecting and mounting recording diaphragms for use. Some discrimination must also be exercised in placing the performers in front of the recording horn. In order to record an artist by the "needle" system with the same strength as may be reached by the "phono-cut" system, it will be necessary that he shall take up a position nearer to the recording horn and exert more vigour in his performance. In the recording of instrumental combinations, the conditions are somewhat changed; for the very numbers which constitute such a combination have the effect of crowding each other out, and only a few of their number can ever be in close proximity to the horn. The intensity of all sound is proportional to and varies inversely as the square of the distance, and the majority of the performers are perforce out of focus and almost out of reach of the recording diaphragm. To obviate this difficulty the employment of multiple recording horns is sometimes resorted to, each of which converge to a common junction. Greater differentiation in tone is thereby secured, but somewhat at the expense both of general volume and sharp definition.

The principal points to attend to in sound recording are the correct distances which the performers should assume in order to secure the maximum of volume, tone, and definition combined; and the angles of inclination which best ensure the unimpeded transmission of the sound waves from their point of origin to the diaphragm. Like light, the angles of incidence and reflection are the same. The waves of directly reflected sound are almost equal in purity and power to those in the line of direct propagation. But the waves of diffraction are retarded in their velocity, and are differentiated and weakened, so to speak. Tyndall points out in his Lectures on Sound how a sonorous wave is refracted by a deviation of its direction. "A large lens," he says "compels the solar rays that fall upon it to deviate from their direct and parallel course, and to form a convergent cone behind it. This refraction of the luminous beam is a consequence of the retardation suffered by the light in passing through the glass. Sound may be similarly refracted by causing it to pass through a lens which retards its motion. Such a lens is formed when a thin balloon, which yields readily to the pulses striking against it, is filled with some gas heavier than air. A collodion, or a thin india-

rubber balloon, filled with carbonic acid gas, answers this purpose. A watch is hung up close to the lens, beyond which is placed the ear, assisted by a glass funnel. By moving the head about, a position is soon discovered in which the ticking is particularly loud. This is the focus of the lens. If the ear be moved from this focus, the intensity of the sound falls; if, when the ear is at the focus, the balloon be removed, the ticks are weakened; on replacing the balloon their force is restored."

Recording experts know by experience, perhaps without knowing the reasons why, how sound is condensed by means of a cone to increase its intensity. By transmitting sounds through a recording horn, which acts as a condenser, the whole impact of their normal intensity is concentrated or focussed upon the diaphragm centre, by which means alone the feeble character of sonorous motions is able to exert mechanical force sufficient to engrave the blank, which of itself offers considerable resistance.

Records which are blatant, harsh, and unmusical, are generally the result of a bad focal adjustment, although a too sensitive recording diaphragm for the work in hand may contribute to a like result. Accurate recording requires no straining after effects in intensity or volume, and the practice is unscientific. Correct focalisation, however, is always of first importance, because this alone will nearly always correct what might otherwise be regarded as an utterly unsuitable diaphragm.

One of the principal reasons why instrumental combinations are recorded with such a relative disparity of volume as compared with the original sounds—unlike the experience with vocals or instrumental solos—is because of this acoustic dissipation. Not only, in general, is the total volume of an orchestral or band record divided by the number of performers in the combination, but most of the parts are invariably flat of tone. Only those instruments which are correctly in focus stand out sharp.

One of the most difficult instruments to record effectively is the pianoforte. Here again we realise that the whole area of the sound-board cannot conveniently be brought into direct focus with the recording horn, so as to give full value to the complete registers. It is usual to direct the horn mouth obliquely to the back of the sound-board, in line with the key hammers, to secure the best average results. The hammers should be " hard," that is, unpricked, to give the most *staccato* result possible, in order to obtain any degree of volume and tonal definition. Stringed instruments of the piano and violin type are always more or less difficult to record, on account of the small amplitude of their strings, as well as their small vibratory area. The violincello and harp are more ponderous. The difficulty of recording the violin with natural volume has been met by Mr. Strch, who has invented a special type of instrument, having a diaphragm and amplifying horn. I do not see why a subsidiary apparatus could not be

attached to the pianoforte to accomplish similar results. Dr. Vincent (the well-known expert in pianoforte construction), has suggested to me the idea of a secondary sound-board to reinforce tonal strength, but I am inclined to favour a scheme of condensation from a simple sound-board, keeping in view the important matter of diaphragm focus.

CHAPTER IX.

THE DUPLICATION OF RECORDS.

In the early days of the original, or cylinder, talking machine records sold to the public were "masters." A number of recording machines were set up in the recording room, and they were started and stopped simultaneously by a simple switch, the actuating power being electric. For vocal records, it was never found to be practicable to run more than three or four machines at a time, whereas no fewer than twenty might be engaged in recording bands. Needless to say, this method was both precarious and expensive, and it soon made way for the duplicating machine, which traced copies from an original. The American Graphophone Co. were apparently the first to introduce this method, in 1896. (See Johnson's patent, 10,066, of 1896.) Bettini and Edison followed with new types soon afterwards, while Petit took out a patent about the year 1900 for a machine of entirely different construction. A cross section view of Edison's duplicator is shown in Fig. 25, and showing the process of producing "Concert" cylinders from "Standard" masters. The principle of operation is as follows: A compound lever, designed to compensate for irregularities in revolving the two cylinders simultaneously, is attached to an

ordinary travelling carrier-arm, which runs on a slide rod by means of a sleeve, actuated by a feed device, and at the extremity of one lever arm is fastened a reproducing ball-sapphire, while at that of the other is similarly mounted a cutting, or recording, sapphire. The styli are kept snugly in contact with the cylinder sur-

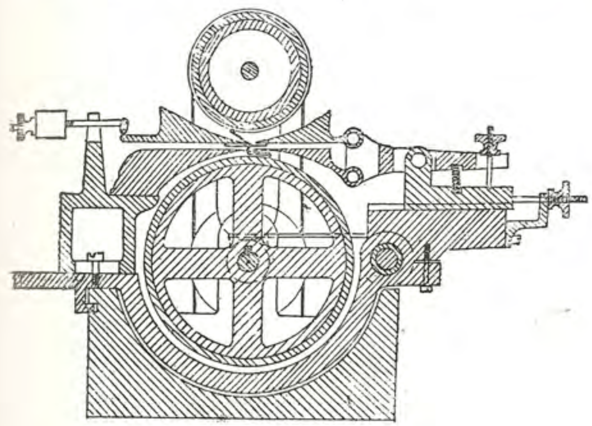


FIG. 25.

faces by means of light tensioning springs, or by small weights, as desired. When the cylinders are revolved—being coupled up by belt and pulleys—the reproducing ball follows the undulations of the original record, and in turn operates the recording stylus, which is in contact with the blank cylinder, thereby engraving similar undulations upon its surface. It is usual to rotate the cylinders in duplicating at a much slower rate than that commonly resorted to in recording, for the purpose of effecting a cleaner tracing of the record. It will be understood that in duplicating, the question of speed, or rotation, has no effect whatever on the pitch of sounds.

The Johnson duplicator was similarly constructed, except as to unimportant details, the

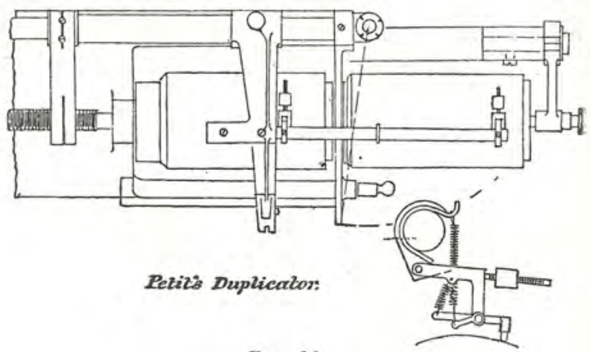


Fig. 26.

chief point being that the cylinders were parallel, while Edison's were mounted one above the other. The Petit duplicator assumed a third form, as the cylinders were in line. A plan view is shown by Fig. 26, with an enlarged elevation sketch of the tracking device at the bottom right hand. In principle, the whole thing is analogous to the pantograph, used largely in drawing, or rather, in tracing enlargements.

The process of duplication by the foregoing means was confined entirely to cylinder records. No satisfactory analogous means were found to duplicate discs. The electrotype was originally employed in the duplication of discs, and it was not until about the year 1900 that the electrotype was applied to the cylinder.

The duplication of records from the cylinder to the disc form, however, has been practised, but never with technical success. Both phonodiscs and needle-discs have been copied from phonograph cylinders in this way, but when electrotypes of the records so made have been employed to press duplicates in the usual way, it has ever been found that in the process of tracing, the fine essential overtones, which give to vocal and instrumental sounds their chief charm, have been almost completely lost, leaving nothing but the coarser sonorous outline. In making comparisons, I have found that "needle" discs, duplicated from phonograph cylinders—although never equal to the original cylinders in correct *timbre* and fine definition —are almost equal to originally recorded "needle" discs, and therefore there are excellent reasons for resorting to such a round-about expedient in their production. But this is only because the "needle" system of recording direct is mechanically crude, and must remain so, since a lever system is necessarily interposed between the recording diaphragm and the blank, which is responsible for the same amount of vibratory loss as with the duplicating machine. The advantage which this system has over the direct recording of the "needle" disc, however, lies in the greater facilities known to all expert recorders to make a perfect "master" in the large cylinder form, and in reproducing it with full volume without appreciable injury. It means so much less working in the dark, so to speak, as in recording needle discs, which can never be effectively reproduced from the wax. Again, the duplication of "mother" matrices may be dispensed with, which is a certain gain in time and money, as well as in the subsequent tone of the record. The explanation of the "mother" matrix will be given in a subsequent chapter.

The type of machine designed to effect this duplication is provided with means to accommodate the cylinder master-record, with a transverse motion to a carrier arm operated by a feed device, attached to which is a compound lever motion of rectangular design, the tracking stylus being swivelled for easy adjustment. If the original cylinder has been recorded at a rotation speed of 160 turns to the minute, and it is desired that the disc shall rotate at half that speed, in conformity with the average disc practice, gearing must be employed to effect this dual motion. The next consideration is, that as the disc is rotating at half the rate of cylinder speed, measures must be taken to give the disc turntable, situated beneath the cylinder, a traverse motion also, quite independently of that actuating the carrier-arm of the

cylinder. This can be varied to suit the requirements of space available on the disc. If we assume that the length of recorded matter upon the cylinder measures six inches lengthwise, and the space available on the disc being only three inches across the grooves, then, obviously, means of displacement must be provided since, otherwise, the duplicating lever cannot occupy two different places at the same time. The cylinder and disc feeds may be the same, although operating independently, and the disc, revolving at half the rate of the cylinder, relatively slows down the traverse movement of the former so that its progressive displacement is proportional to the distance required to keep the duplicating lever parallel.

The difficulty about duplicating is that the least variation in the set of the lever—the kind of job to be assigned to a very skilled mechanician—will affect the character of the copy and make it somewhat hazardous to ensure two copies from the same original being alike. This was a very serious obstacle in the days of cylinder duplication, and before the moulding process was introduced. Also the continuous use of the master record for the purpose of making copies subjected it to much wear, reducing its original sharpness and other qualities. The adoption of the electrotype for the moulding process effectually superseded the mechanical duplicator, and enabled any number of duplicates to be secured from an original by cheaper means, and with the added advantage of their being exactly alike in all essential particulars. Greater care and expense could henceforth be bestowed on the production of the "master" record itself, and a great improvement was soon marked in the quality of records manufactured by this method. The cost of production was reduced considerably, and there were fewer elements of possible failure, technically. By the former process, the blank upon which the record was to be copied was required to be faultlessly moulded and shaved. The latter process involved only the moulding without the shaving, and enabled harder compositions to be used, which increased strength of tone, as well as giving greater durability to the records than the softer recording or duplicating blanks could reasonably be expected to provide.

CHAPTER X.

THE PRODUCTION OF MATRICES.

A large number of treatises have been written by qualified writers on the electro-deposition of metals in general that there is no occasion to enter into a chemico-metallurgical description of the art and its various processes in these pages. To the student who wishes to make himself capable in this branch of the talking machine art, I recommend a close reading of the text-books, or, better still, the opportunities afforded in the classes which are set apart for instruction and practice in the several Polytechnic institutions which have grown up during the last few years. Much may be learned from books, nevertheless, and both courses may be embraced with profit by those who seek the fullest comprehension of this interesting and useful work. There are many things to know, however, which are not to be learned from the text-books or classes, and which have come only from experience, in the efforts to perfect the comparatively recent talking-machine record. These things are known only to the comparatively few experts who have made this particular work their close study, with opportunities for scientific experiment. These things I shall deal with at some length.

The art of electro-metallurgy rests upon the fact that an electrical current tends to decompose a metallic solution into its constituent elements, and throws the metal element upon any surface prepared with a conducting surface to receive it. Electro-plating and electrotyping are different in that the former, the metal deposited is amalgamated with the substance of the surface so treated, whereas the latter is treated in order that the conducting agent, and with it, the deposited metal, may be easily separated. The latter process enables the copying of almost any substance, if superficially treated by metallic, or conducting agents. It is the process by which it is possible to secure a metallic obverse, or negative, from a wax or similar record. The art dates only from the early part of the present century, and was first practised by printers, in the duplication of types and blocks. It is employed very extensively in many departments of art.

Several sources of electrical energy are available for electrotyping. Firstly, there is the simple cell, of which Professor Daniel's is the most simple. Secondly, there is the accumulator, which may be charged by the current of one or more simple cells, or by that generated with a dynamo. Thirdly, the dynamo itself, by far the most rapid, cheap, and infinitely more economical and efficient in every way to the other and older systems. Indeed, it is difficult to know how the record matrix could be satisfactorily or commercially produced at all without the aid of the modern dynamo and reciprocating devices. It is possible, however, to do without it, and I have made these matrices in an experimental way by all the methods referred to. But the dynamo is the thing. (See Fig. 27.)

The principle of the dynamo depends upon its ability to transform mechanical energy into

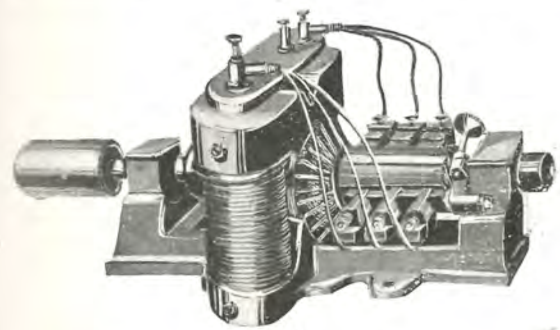


Fig. 27.

electrical energy. It therefore requires to be driven by a motor of some kind, and it matters not what type of motor is selected for the purpose so long as its horse-power is at least equal to the work imposed on it by the capacity of the dynamo and subsidiary resistances. Electrotyping requires a relatively low pressure, rarely exceeding 5 volts, while the maximum current which the dynamo is capable of generating or delivering at its normal speed of armature rotation must always be proportional to the superficial area of the work to be covered. The resistance of a dynamo may be measured by a multiplication of its voltage and ampere capacity, which gives the number of watts. Thus, it is customary to designate a dynamo as having a capacity of so many " watts." For example, a dynamo yielding 5 volts of pressure and 75 amperes of current is called a dynamo of 375 watts capacity. Conversely, a dynamo of 75 volt capacity and 5 amperes is the same thing. Now, one horse-power is the equivalent of 746 watts, and a dynamo of 5 volt capacity at 75 amperes—sufficient for the deposition of, say, two standard cylinder matrices at one time—will take about ½ h.p. to drive it, without reserve for the incidental resistances, shafting, etc. A one h.p. motor, therefore, is the minimum of motor capacity to operate such a dynamo effectually.

The dynamo is usually driven by means of an electric motor, although there are self-contained motor-generators which are connected in the shaft by couplings, thereby dispensing with additional shafts, pulleys, and belts. These are rather expensive, however, and are only to be found in first-class establishments.

A volt and ampere meter, as well as a resistance board, are necessary to be interposed in the circuit from the dynamo to the bath, the latter for regulating the current as required, and the former for indicating the current actually passing. The bath itself may be made of glazed earthenware, or may be constructed,

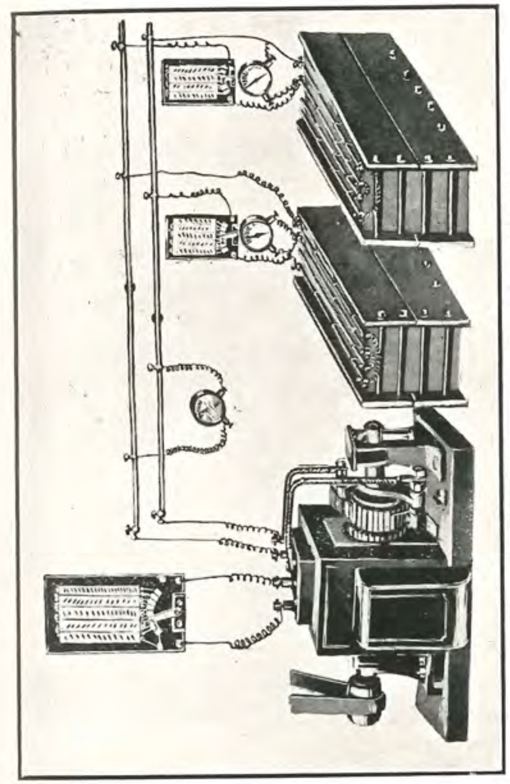


Fig. 28.—Arrangement of Depositing Plant.

if required for a large amount of work, in wood, lined with sheet lead. The joints of the lead lining should never be soldered, but should be fused in the well-known way. Such baths are supplied by all the principal makers.

In dealing with this branch of the record work, it is desirable to point out the several "secret" methods so successfully carried out by expert operators, and which are not referred to in any of the standard books upon the subject, and indeed which are very closely guarded by the operators themselves, who have gradually evolved these methods in the work of securing the finest surfaces attainable by the electrotyping process. The ordinary methods in use by the electrotyper for printing purposes would be quite inadequate for the production of record surfaces. In surfaces for printing, no great care need be taken to obtain a faultlessly smooth surface, as the ink and pressure which are applied to such surfaces overcome all ordinary shortcomings in that respect. But the record matrix surface must be the very finest which the most scientific processes and the combined skill of the workman are able to effect, inasmuch as the smallest pinhole or abrasion, however microscopic, will be greatly magnified by the reproducing apparatus after the record has been moulded from it. It may be truthfully said that the record matrix maker begins where the ordinary electrotyper leaves off. He is required to be expert in his work to the highest degree, and few of such

craftsmen are to be found, comparatively speaking.

The depositing solution consists of a saturated solution of blue vitriol, or sulphate of copper. The crystals are best dissolved in distilled water, but before the solution is conveyed to the bath, it should be strained. A sheet of unbleached cotton fabric will effect this as well as anything. One quart of water and 4oz. of the best sulphuric acid must then be added to each gallon of the above saturated solution and thoroughly stirred, in order to render it uniformly acid. Anodes of pure copper should only be employed, which have been made by the electrolytic process itself, and which are therefore free of impurities. Electrolytic copper deposits give a much finer surface than ordinary commercial copper sheet. For cylindrical records, the anodes are made cylindrical, to encircle the record, that is to say, a sheet is rolled as a tube, leaving the edges unjoined, which does not in the least matter. For the ordinary standard cylinder records of about two inches in diameter and four inches in length, the anodes should be about six inches in length and in diameter. These are now supplied by trade houses, about a quarter of an inch in thickness. A couple of holes drilled opposite each other at one end of the anode will serve as a means of slinging it, or suspending it, in the bath by a length of stout copper wire, the latter forming a path of the circuit.

It is a well-recognised principle that the greater bulk of solution favours the more reguline character of the deposit. Nothing will be saved, therefore, in the employment of baths which are small. The superority of a large volume of solution is due to the simple circumstance that it takes longer to impoverish. It may rightfully be inferred from this that a small bath may be successfully employed, provided means are resorted to for a constant renewal or addition of fresh solution to be made. In all cases, the solution should be constantly stirred, as it will naturally tend to become more dense at the bottom of the bath and poor in the upper strata. Apart from the need to continually diffuse the solution by mechanical means, a scheme has been devised to give an even character to the deposit, as well as to accelerate the rate of deposit, which consists in rapidly rotating the cathode (the record) in a fixed position inside the radius of the anode. A small pulley is attached to the spindle of the record holder, which may be actuated by means of a belt or cord from the shafting of the motor which drives the dynamo. The speed of rotation must be governed by the

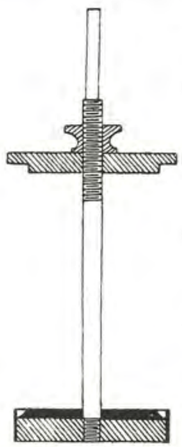


FIG. 29.
A RECORD HOLDER.

current tension passing through the bath, as its resistance is largely proportional to its velocity of motion. An illustration of the type of record holder in use is shown in Fig. 29. It is constructed of insulating material, such as vulcanite, with soft rubber pad rings attached to the inner side of the clamping discs, to grip the more or less delicate wax record without fracturing it. A metal stem is fixed in the main vulcanite spindle, to be used as a conductor of the current, to which a length of very fine copper wire may be attached and carried down to the record edge, being wound around the upper extremity of the record, to make a metallic connection to the face of the record itself, which has been previously rendered conductive by graphite.

It will be understood that the wax composition of which the record is made is, like the vulcanite holder, a non-conductor of electricity. It becomes imperative, therefore, to metalise the record surface, and the usual way to do this is to lightly brush very fine graphite over the same, with a camel hair brush, until the whole is properly covered, when the superfluous graphite must be absolutely removed. Particular attention should be paid to bring the fine copper wire coil in intimate contact with the graphite film. When about to immerse the record in the bath, by means of its holder, it is very advisable to dip the same into, or otherwise cover the graphited surface with, spirits of wine, in order to prevent the formation of air bubbles on or near its surface when bringing it into the solution, and which otherwise might be productive of small holes or depressions in the matrix face.

There are several other methods of metalising wax surfaces, but by far the most perfect is that devised by Mr. Edison and known as the vacuum process. The record is rapidly rotated in a vacuum jar, between gold wire or strip anodes, and by means of high-tension current, the gold is literally vaporised and deposited as a fluid film. The old idea that metals are essentially deposited in grains no longer holds good. This method ensures the most perfect matrix surface possible, and saves the necessity of gilding the matrix, which is usually done when the copper is deposited first by means of a graphite coating, for the purpose of protecting the copper from the effects of oxidation and other corrosive elements in the heated wax during the moulding.

Solutions of various metallic salts, such as chloride of gold, and of platinum, or silver nitrate, have been employed to metallize record surfaces without much success. Nearly equal to the volatilized gold process is that by which such surfaces are treated with a preparation of the very finest Dixon graphite (98 per cent. pure carbon), which retails at something like 40s. per lb. A small quantity of this goes a very long way, and the cheaper qualities are not to be compared with this. It is beautifully soft and highly conductive, and it may be greatly

improved in the latter respect by gilding or silvering before use. To gild the graphite grains, dissolve in a bottle, 1 part of gold chloride in 100 parts of sulphuric ether. Mix well, by shaking the bottle, the addition of 50 parts of the graphite. Expose the mixture to sunlight, with occasional stirring, until no trace of the ether is left. If it is desired to silver the graphite, instead of gilding, dissolve 3 ozs. of crystallised silver nitrate in 3 pints of distilled water; mix this solution with 2 lbs. graphite, or follow equivalent proportions. Dry in a porcelain vessel and calcine at a red heat in a closed crucible. When the mixture is quite cool, it should be carefully pounded and strained through a fine gauze. The conducting power of this preparation is better than the previous one, but the gilding is less troublesome and is recommended for preference.

Either of these preparations are applied with a soft camel or sable brush, just as ordinary plumbago is applied. It is rather the care and the skilful manner in which either of the preparations are applied to the delicate wax surface than anything else which ensures the highest technical results. It is customary to support the record holder, with the record placed in position, between centres, and slowly revolve the same during the application of the graphite. The least possible quantity must be used with the least possible pressure. So long as the entire surface is actually covered, that is all that is necessary. The record must then be finally dusted, when the operation is completed, to rid its surface of any superfluous or loose particles of the graphite, which, if remaining in the sound-wave grooves, will give rise to corresponding depressions in the matrix face, and so distort the tonal purity of the record moulded therefrom. It may also with advantage be brushed over a number of times for the purpose of polishing the surface, this ensuring a cleaner and brighter deposit. But this must be very carefully done, in order not to bruise the delicate impressions in the wax beneath it. The record and holder should then be removed from its temporary supports and carefully flushed with alcohol. Care should be taken that the entire surface is covered, and the object of this is to prevent air-bubbles attaching themselves to the record when it is immersed in the depositing bath.

The metal stem of the record holder should now be fastened in the neck of the pulley spindle on the framework above the bath and clamped firmly by means of a set screw. If the bore of the pulley spindle is sufficiently extensive, the holder may be raised or lowered as desired to maintain the record in the correct position in the bath, which should be on a level with the anode, and, of course, inside of it.

Assuming that the connections from the dynamo to the bath have been properly made, with the right strand of cable to withstand or carry the current, the motor may be started and the record revolved by means of a pulley and

cord from the main shafting. The rate of rotation, I have found by experiment, should be somewhat proportional to the current pressure—the greater the pressure the higher the rotating speed, up to certain limits. I have found three to four hundred revolutions per minute to be quite practical for rapid work. The switch of the dynamo may be regulated to permit of not more than 2 or 3 amperes of current passing into the bath for each record of the standard dimensions for some little time, until a thin coating all over the surface has taken place. If the internal resistance of the bath is considerable, the amperage should be increased to overcome it. The weaker the current the finer will be the grain, or character, of the deposit. It is necessary that the preliminary coating, which ultimately forms the mould, shall be as smooth as it is possible to get it; but when this condition is once secured, a more rapid deposition may take place; and a current of 50 amperes at a 5-volt pressure will not be too great, although this is advisable to be gradually applied. The deposited metal will be coarser and nodular in structure on the exterior, but this is of small consequence, inasmuch as it can easily be turned down in the lathe when it has grown to the required thickness for use, which is about one-sixteenth of an inch, in general practice.

If the question of time is not of great importance in the deposition, a low current may be employed throughout, for this unquestionably yields a superior atomic organisation of the metal, giving it greater tensility as well as a finer texture. But good pressure is a great secret to obtain this result. I have made matrices by this slower method which have shown on their exterior of the ordinary thickness, every wave undulation of the records nearly as definitely as upon the record itself.

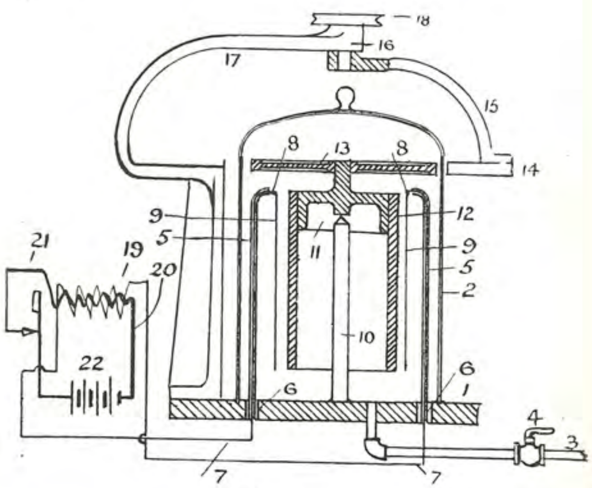


FIG. 30.

When a film of gold has been deposited upon the record by the vacuum process, it will be necessary to exclude it from the air in a sealed tin case, or other receptacle, in which a mandril, covered with velvet strips or felt pads, is fixed centrally at the bottom, if the backing up, or

electrotyping operation, is delayed for any length of time. The precaution of flushing the gold film with alcohol should not be neglected, to obviate the presence of air-bubbles between the two metals. Gold and copper have a wonderful electrical affinity for each other, and so no additional treatment of the gold surface will be necessary. The coppering process here, to be precise, is not electrotyping at all, but electro-plating. The gold is plated with the copper merely for strength and for economy.

A general description of the Edison application of the gold-depositing process in *vacuo* is set out in the British patent specification, numbered 13,693, of 1900. The construction of the apparatus is shown in Fig. 30. A base (1) carries a vacuum chamber (2) in the form of a bell; (3) is a pipe for exhausting the air from the bell by the aid of a suitable pump, not here shown, and (4) is a valve to maintain the vacuum when obtained; (5, 5) are two insulated supports, held by vulcanite bushings (6). In both of these supports a conductor (7) is placed with a hooked extension at (8). In operation, strips of gold are suspended from these hooks, which constitute the electrode (9); (10) is a support situated between the electrodes and carrying a rotatable head (11); (12) represents the record to be covered, which is held in position on the head (11) from its tapered exterior; (13) is an armiture connected to the head (11), and (14) a horseshoe magnet mounted outside the bell and serving to attract the armature;

(15, 16, 17, and 18) show the accessory connections—the arm, shaft, bearing, and pulley—which latter is rotated by any suitable source of

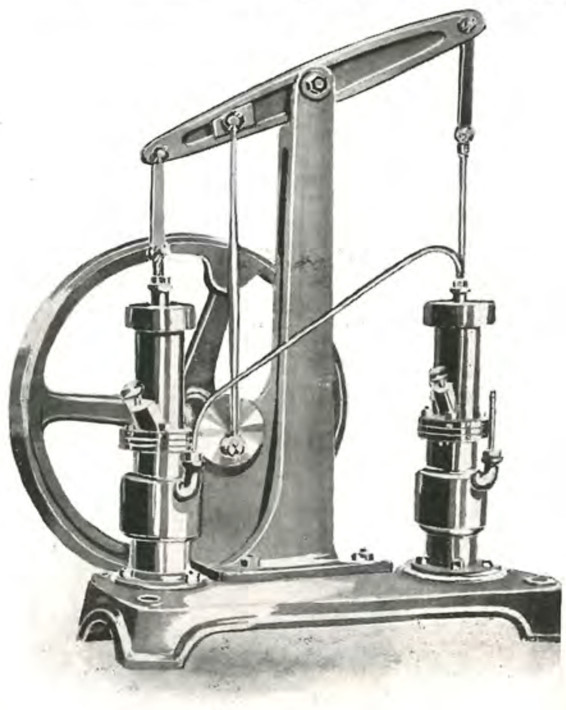


FIG. 31.

power; (19) represents a large induction coil, the secondary wires of which are carried to the conductors (7), while the primary conductor is

included in a circuit (20), with a vibrator (21) and a source of current (22).

The cost of this appliance is very considerable, the intensity coil consuming the larger part of the expense. Even a good vacuum pump cannot be procured for less than £5, some types costing very much more. Fig. 31 shows a type of pump manufactured by the Pulsometer Co., of Reading.

The bell is required to be of good quality to antagonise the possibility of explosion by the impact of the outer atmospheric pressure. The process of operation is as follows: The record is placed in position on the rotatable head, as shown in the figure, and the bell is then firmly placed in position over it. A vacuum is created in the bell—that is, as high a vacuum as can be obtained—by the pump, which extracts and discharges the air from the bell. The motion is started and the record is rotated. The current is next switched on, and so regulated as to produce a silent or brush discharge of high tension, which passes between the two electrodes, encountering the rotating record in its path and leaving the vaporised particles of the gold upon its surface. Great care is required in the work on account of the heat generated (not being a perfect vacuum), and it is sometimes necessary to perform the complete operation at intervals. Cooling devices are sometimes employed, but Mr. Edison makes no mention of their necessity.

When the record is completed, and is subsequently covered with a copper deposit of about one-sixteenth of an inch in thickness, as previously mentioned, it should be taken from the bath and thoroughly washed in clean water to free the deposit from salts. After removal from the holder, the matrix should be mounted, together with the wax record within it, on a short mandril between the centres of a lathe, and with a dividing tool should be cut and trimmed clean at the extremities. When this is performed, the record may be released by the assistance of any cooling process, when it will shrink away from the matrix; or, as an alternative, it may be dissolved out by heat in an iron saucepan over a jet. In the latter case, it will be necessary to clean the interior surface of the matrix with a little paraffin oil applied by a tuft of soft cotton wool, ultimately finishing the process with a new and perfectly clean pad of cotton wool moistened with benzine. The matrix is then ready for internal polishing. This will not require to be done, of course, when the record has been gilt by the Edison method, but when the record has been directly "typed" with copper, it will be necessary to do so, preparatory to gilding it, to prevent oxidation or other corrosion. The polishing is done by inserting the outer surface of the matrix between extended jaws of a lathe chuck and revolved at high speed, while a long hog-hair brush, occasionally dipped into a mixture of fine jeweller's rouge or fine metal polish and paraffin oil, is held very lightly and carefully against and passed over the matrix lengthwise. Some matrix

makers prefer to attach a circular brush, supported by a spindle, to the lathe head, and hold the matrix in the hand to carry out the polishing operation, but this practice should be discountenanced as involving more risk of injury and irregular treatment. A very little common-sense will make it quite obvious that the whole of the matrix surface could not be uniformly polished in such a manner.

When, after microscopic inspection, it is ascertained that sufficient friction has been applied to the surface to render it quite smooth without sensible interference with the vibratory undulations of the record, it is then ready for finishing. This is done by again putting the matrix into the lathe chuck as before, and by means of a soft cotton mop with a diameter about equal to the interior of the matrix, pressing it against the surface in conjunction with such a medium as dry Sheffield lime, or gilder's whiting. After this treatment, the matrix is ready for gilding.

Only a very fine film of gold is permissible or necessary, which may be deposited in a few minutes, after the usual preparations. The matrix must first be immersed in a solution of caustic soda, and this is best done in an enamelled iron vessel. The soda solution may contain 1 lb. of caustic soda to the gallon of water. The solution should then be raised to boiling point and the matrix covered by it for about ten minutes. It must then be thoroughly rinced in clean water. Following this, it may be dipped in a solution of potassium cyanide, 1 oz.; red oxide of mercury, ½ oz.; and water, 40 ozs. It should remain in this solution until a silvery appearance takes the place of the copper, when it should be again rinsed in boiling water. It is now ready for the gilding solution. To prepare this, dissolve 1oz. of potassium cyanide in 24 ozs. of warm water, and place it over a gas jet until its temperature is maintained at 120 degrees Fahrenheit. If this is prepared in a glazed earthenware jar sufficiently large to conveniently form a bath for the matrix, holding, say, half a gallon or more of the solution, the matrix may be hung therein by means of a piece of copper wire looped around its upper extremity, and which may constitute one of the conducting wires in the circuit. A very thin platinum wire should be used *in the solution* for supporting the anode, which can be joined to copper wire outside the solution. The anode must be gold, and a small sheet, or bar, weighing, say, half an ounce, or even less, will present sufficient surface, and may be raised and lowered by the hand inside the matrix, to bring the anode in something like equal juxtaposition along its entire surface; or a rod of gold, equal in length to that of the matrix, may be supported quite stationary in the centre thereof. It is not necessary, however, for the gold anode to be large. A current of ½ ampere, or less than 1 ampere, is generally sufficient to deposit a fine layer in a very short time. Other things being equal,

the quantity of current entering the bath should be proportional to the anode surface, so that the larger the anode and corresponding wires, the more rapid will be the rate of deposition.

The anode wire is connected to the positive conducting wire and the matrix to the negative, as in the copper bath.

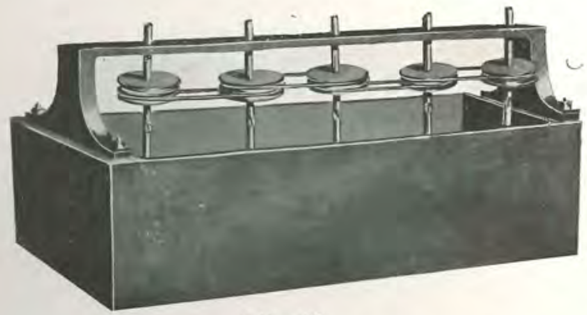


FIG. 32.
METHOD OF ROTATING CYLINDERS IN COPPER BATH.

Many other variations of solution and arrangement may be made in the process of gilding. The operator will select the method which seems to him the best and most economical. By most of the known methods the gilding of matrices is not a costly matter, as an anode possessing the requisite surface capacity will not be readily dissolved away, and quite a number of matrices may be gilded with an anode of gold of the size and value of a sovereign.

Van Horne recommends the following formula for bright gilding:

Potassium Ferrocyanide.........	2 ozs.
Carbonate Soda	2 ozs.
Chloride of Gold	5 dwts.
Water	1 gal.

The ingredients should be dissolved separately in portions of the water; the soda solution should be added to the potassium solution and heated to the boiling point. Then the gold solution should be added and boiled for about 15 minutes. After cooling, sufficient water should be added to make up for that lost by evaporation, when it should be filtered. A current of 3 to 4 volts may be used with this solution, which yields a fine bright colour on copper, and on most other metals.

Pure chloride of gold contains 65 per cent. of gold and 35 per cent. chlorine, from which we know that an ounce of chloride of gold contains 312 gold grains. The peculiarity of gold solutions is that good ones may be made with such variations as from 15 to 300 grains of gold to the quart, according as they are to be used hot or cold, or according to the source of the current, and according to the colour of the deposit desired. In the gilding of matrices, the last-named consideration has no importance whatever. Better work is done with a hot than with a cold solution, and the work is more expeditiously done.

The proportion of cyanide in the solution also affects the colour of the deposit. It is also

related to the strength of current employed. A low pressure requires more free cyanide than a high one, as a rule, which tends to reduce the resistance of the bath. The metal, of course, performs the same office; and not merely the colour, but the character, of the deposit will be modified if the correct proportions are not recognised. An excess of cyanide yields a pale and weaker texture, whereas an excess of metal produces a brown deposit, if the current is not managed with circumspection.

Hot solutions work well with a much smaller proportion of metal, 30 grains to the gallon producing good work. Cold baths, by comparison, require three times the quantity. Economy, therefore, will always recommend the hot, as preferable to the cold, solution. Further, the deposit is finer-grained. But this solution requires constant attention, as hot cyanide has small effect on metals. A strong stock solution should always be on hand to replenish the bulk. A formula for this is:

Chloride of gold	1 pt.
Cyanide	1½ pts.

Dissolve separately in distilled water, and mix the two together.

Possibly no metal is so easy to deposit as gold, and no metal so likely to vary in its texture and colour in the process. The chief causes conducive to such variation are: (1) the character of the depositing solution; (2) its temperature; and (3) the strength of current used. The potassium cyanide solution, with variations, is the most favoured solution in use, on account of the general satisfaction which it gives.

When the matrix has received the film of gold as required, it should be well rinsed in clean, warm water, dried with finely-sifted box-wood sawdust, and subjected to the polishing and finishing treatment as described for the copper surface, but in a far lesser degree. If the deposit is fine, only the treatment with a soft buff and Sheffield lime will be necessary Separate brushes and buffs must, of course, be employed, and kept from accumulating dust, when not in use, in closed receptacles. If there is one word which means more than any other in this branch of the art, it is *cleanliness*. No good work can possibly be done without a chemical knowledge of what this word stands for.

The matrix is now ready for taking an impression in wax or celluloid, as required. The apparatus required to accomplish this will be described in a subsequent chapter, or chapters.

The making of a *disc* matrix is next to be considered. The surface of the record will require to be metallized in a similar manner to that described in connection with cylinders. Before this is done, a length of clean copper wire should be stretched around its edge, in the small groove which was cut in the wax blank at an earlier stage. The two ends of the wire should be carefully twisted to form a joint and their

superfluous lengths may be formed into a loop, or hook, for the purpose of slinging the record in the bath. Perhaps a more up-to-date method to effect this with a minimum of preparation is the use of vulcanite clamp holders, the grips cushioned with soft rubber, and by means of which the record may be placed in or taken out very quickly. This, however, is rather a matter of detail than of principle. The same solution should be used, but the bath must be of sufficient depth so that the record is thoroughly immersed and yet is not in contact with any part of the bath itself. The anode should be stout electrolytic copper, in plate form, and somewhat larger in superficial area than the record to be covered; and this must be slung similarly in the bath, by means of a similar support, and arranged to face the recorded surface of the wax disc at a distance of 2 or 3 inches, according to the current employed. Much of the foregoing information in relation to cylinder deposition will be equally pertinent as to discs. The only important point of difference consists in the means for agitating the solution and ensuring a reguline deposit.

Obviously, the disc cannot be rotated with the same ease and simplicity as the cylinder, on account of its different form. Other means, therefore, must be resorted to, in order to accomplish the same result. Of these means there are a variety in practice, each supposed by their respective operators to be superior to the other, whereas there is little difference in results. A *cam* arrangement, worked with power, is sometimes used to sway the anode to and fro, which is a simple, if not the best

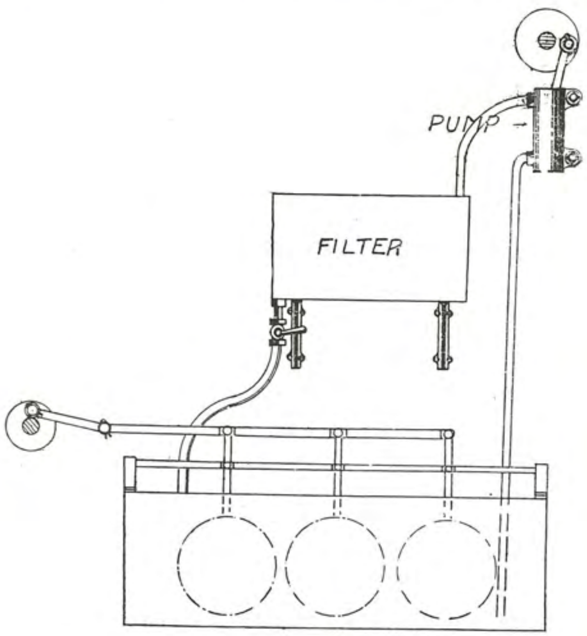


Fig. 33.
The Combination Agitating System for Discs.

device. Sometimes, too, a small paddle-wheel, or screw, arrangement, is rapidly revolved from an extended shaft, well down in the body of the solution, and as near to the record as pru-

dence will allow it to be placed without disastrous effects upon its fragility. There is also the " Growler," as known in the trade—a form of centrifugal pump, operated by power, to keep the solution in constant movement.

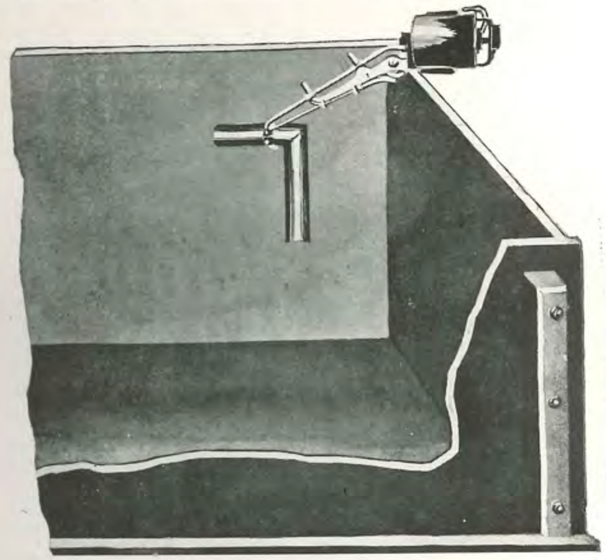


Fig. 34. The Benson-Leaver Agitating System.

This is very effective for fine surface depositing.

The Benson-Leaver system is still another scheme to reach the same result by air pressure. Not only are better surfaces obtained by the use of these devices, but the rate of deposit can be accelerated greatly, and greater pressure can be employed. In addition to these advantages, the deposit is more close and tough, and its tensility is far higher than otherwise. It is claimed that the Benson-Leaver system enables a much higher current density to be used than with any other system, yielding cleaner, smoother, and denser deposits of metal. The apparatus is both small and light, and is not expensive as an attachment to a bath. It is furnished with a small motor, which can be run from the depositing circuit, if required. The parts which project into the solution are made of celluloid or vulcanite, and where made of metal are heavily coated with lead. Fig. 34 shows the scheme attached to the bath.

The operation of the attachment consists in the continuous pumping of the solution, vertically and horizontally, and so hastening its diffusion.

For rapid deposition, a process of diffusing the solution is quite indispensable, because the current, being strong, very quickly impoverishes it near the cathode; and this results in a very poor quality of metal at that point where the highest quality is required. At length, there is insufficient metal in that quarter of the bath to carry the current, and, as a consequence, the current soon begins to decompose the water of the solution when the evolution of hydrogen causes nodules to be formed on the cathode (record) surface, in the retarded normal deposition.

With regard to the source of current itself, I have mentioned that the dynamo is the best available substitute for the cell or the battery. It is superior in every way on the score of constancy. Yet I must not omit to point out that even the dynamo is not a perfect source of constant current, and few dynamos yield their estimated maximum current output continuously. By far the most perfect method is to employ accumulators in connection with a charging dynamo. The accumulators, if kept in good condition, will invariably deliver a larger maximum current of stable value. I have stated, also, that a low-pressure dynamo, or other source of current, yielding only about 5 volts, is all that is required in the deposition of the cylinder matrix, but this is to be qualified somewhat in considering discs. When waste of current is less important than a superfine surface (which is worthy of consideration in the making either of disc or cylinder matrices), a dynamo of far higher capacity may be employed with advantage. A surface of much greater smoothness is obtained from a high-tension current than from a low one, when, by interposing resistance, the former is cut down to the same pressure as that of the latter, without such resistance.

The specific gravity of the solution should frequently be ascertained, and its quality maintained when much work is in progress, prior to which the solution should be briskly stirred with a glass rod, or a strip of plate glass. The gravity should register about 21 (Baume) for good, all-round results. The top of the solution should also be skimmed every morning before use to clear away any floating particles of dust or foreign substances, which may readily contaminate it. The positive pole of the dynamo, or lead, should be connected up to the anode and the negative to the cathode, by means of stout copper wire. When the record is placed in position, and the agitation of the solution has begun, a very few amperes of current should be switched on until the surface is quite covered, after which a fuller current may be passed, when the deposition will proceed more rapidly. When the matrix has grown to about one-sixteenth of an inch, or less, in thickness, taking several hours to do this, the current may be cut off and the record removed from the bath. It should be well rinsed in warm water, and, as the copper will have been deposited not only on the record face, but halfway over its edge to the ring of copper wire which held it in the bath, it can safely be transferred to the face-plate of a lathe, where the operation of cutting its periphery clean and to dead size may take place. The matrix proper is then complete, but it has to go through one or two further operations before it can be used for the production of record positives.

In commercial practice, on the other hand, the "master" matrix is never used for pressing records, but only for "mothering" and

duplicating "stampers," as they are called by the workmen. A stamper is a working matrix for pressing records, and as such is merely a duplicate of the master matrix. But, as a stamper is to all intents and purposes identical with the master matrix, I propose to carry the reader over to the further operations just mentioned to complete the matrix for the process of pressing records for the public, leaving the description of matrix duplication for the following chapter.

Having trimmed the matrix in the lathe to correct size, it is necessary to "back it up" for strength and to prevent buckling. A disc of copper, or brass, is turned flat on either side, and true to size in diameter. One side of this is "tinned" with solder, as is also the back of the matrix, after it has been skimmed and rendered quite level. The two surfaces should then be sweated together with additional solder in the bed of a powerful press, which must be heated sufficiently to melt the solder. A firm squeeze of the press must then be given to amalgamate the two, and either be permitted to remain while being gradually cooled by cutting off the source of heat, or cooled by artificial means. When this has been satisfactorily carried out, the back of the matrix should be faced true and the central hole should be drilled.

The exact position for the hole will be indicated by the small conical protrusion, the top of which should be first carefully removed or flattened. The drilling should be done in the face plate, to ensure the hole being truly at right angles to the plane of the matrix. The outer edge must lastly be trimmed to exact size to fit the dies of the press.

All this accomplished, the matrix must next be polished in a similar manner as described in the previous pages in connection with cylinders. This can be done while it is still in attachment with the face plate. The disc matrix is not gilded, but plated with a tougher metal to resist the strain, presently, of the hydraulic press. Whether the matrix is plated with nickel or steel is a question for consideration. The former is the metal generally adopted, being hard and close grained, and susceptible of a fine surface by polishing.

It may be remarked that in practice only a comparatively small number of records can be pressed from a matrix before it becomes necessary to strip and re-plate it, on account of the enormous pressure to which the matrix is subjected, and which is necessary, with the dense plastic material of which records are made. The needle discs require considerably more pressure than those of the cylinder cut type, owing to the finer dimensions of the track. A pressure of half a ton to the square inch is required for average work, and this is a great strain upon the delicately marked walls of the record track.

Nickel needs a higher tension of current than copper for deposition. Much gas is given

off in the process, especially in starting. The solution should be strong to prevent absorption of gas by the deposit. The less gas evolved the better, and the minimum current will yield a better quality of metal. The matrix must be kept in motion to secure even deposition, and the best deposits are those which are matt or dull in appearance, and not brilliant when removed from the bath. They are readily amenable to a high polish, to ensure brilliant surfaces afterwards, by mechanical means, but brilliant deposits are never durable.

Nickel anodes, of course, must be used. Platinum is unreliable. Metallic nickel is unfortunately very impure, but the best obtainable should be employed. The easiest solution to work is probably one made up of the double salt of nickel and some alkali. A more expensive, though more efficient, solution is cyanide of nickel dissolved in potassium cyanide solution. The double sulphate of nickel and ammonia, dissolved in water to saturation, and afterwards reduced for working purposes, is another excellent medium. There are, indeed, a large variety of solutions which may be used with peculiar advantages in the deposition of nickel.

The plating of matrices by steel offers certain advantages when the need for stripping and re-plating is considered. The steel facing of electrotypes is exceedingly durable, and yet, when it does wear down, steel may be very easily dissolved clean from the copper base without injury. The stripping of nickel from copper, on the contrary, is a difficult operation, and entails much technical skill and care. The deposit of steel requires to be carefully conducted, and the matrix must be chemically cleaned with caustic potash and cleaning mixture, being subsequently washed in water.

The best salt is the double chloride of iron and ammonia. Urquhart mentions the particulars of a solution which is a modification of Professor Böttger's process. To prepare the usual solution, clean iron wire, in coils, should be dissolved in muriatic acid until the acid is quiet. The employment of gentle heat at the close of the operation will facilitate the decomposition, as the acid will be then weak. For 58 grains of iron dissolved, add 53 grains of ammonium chloride to the solution. A small quantity of glycerine will diminish its tendency to spoil.

"Another way," says Urquhart, "is to dissolve 25 lbs. of carbonate of ammonium in 17 gallons of water. The iron is to be dissolved into the solution by immersing in it a clean anode of charcoal iron, connected to the copper pole of a battery of three or four Bunsen cells. To the zinc pole attach another iron plate, and test for deposit by occasionally substituting a copper plate for the cathode."

The anode in the bath may be a sheet of

charcoal iron. The deposit does not take place immediately on the electrotype being put into the solution. After it has been immersed some few minutes it should be removed and brushed with whiting and water and cleaned and again immersed. This operation should be repeated three or four times, when a sufficient deposit will have been effected.

The solution must be kept in good condition by the addition of about half a pound of carbonate of ammonium every few days. When the deposit is completed, the matrix should be very thoroughly washed in boiling water, followed in cold, with brushing. It should then be dried off, cleaned with benzine, and oiled to prevent oxidation by moisture, until it is required to be used.

Another method is to fill the bath with a ten-per-cent. solution of sal-ammoniac, and hang a sheet of iron on one side in the same. The sheet may cover one side of the bath entirely. On the other side, a piece of copper sheet may be hung, and after making the connections a current of about 10 amperes passed through the solution for 48 hours. The solution is then ready. The iron plate constitutes the anode, and by substituting the matrix for the copper sheet, after it has been cleaned and soaked for a few minutes in a ten-per-cent. solution of cyanide of potassium, it is ready for deposition, which may be effected by a two-ampere current in a very short time. The white deposit will soon assume a grey colour, which may be polished brilliantly with flour emery and water. After several of such immersions and polishing, the deposit will be thick enough.

The removal of the steel face, when required, may be effected with a ten-per-cent. solution of nitric acid.

CHAPTER XI.

THE DUPLICATION OF MATRICES.

Having obtained what is known as the "master" matrix, the next operation is to secure a number of working duplicates. There are several ways of doing this. The most rapid, and undoubtedly the most effective, way is to take impressions from the original matrix in thin layers of highly polished pure lead, which are thickened up by successive layers, and pressed together, a process invented and commercially worked out by Dr. Albert. A later method is to press the stereotype in a sheet of pure lead of about one-sixteenth of an inch in substance, and I have seen beautiful examples of these pressings made in a very few minutes. The process has the advantage of rapidity, and the work may be then electrotyped in the same manner as the original wax record was done. It is usual to finally face these lead sheets, before subjecting them to the enormous pressure, with fine graphite, which not only assists in polishing their surfaces, but may fill in any small holes or interstices in the metal not visible to the eye, and thus automatically make good any possible defect, and, in addition, will prevent any amalgamation by pressure of the two respective surfaces, ensuring a clean face. The employment of this process in the duplication of printing blocks is now becoming extensive, owing to its simplicity. It will be understood that soft copper deposits in the original matrices will not work efficiently with this process, owing to the enormous pressure required, but the tough deposits of high-tension currents will usually be successful.

Another process consists in pressing a plastic composition into the original matrix and taking electrotypes therefrom as "stampers," or working matrices. Many substances, including the metallic soaps, have been tried; and while the latter is the successful method with regard to cylinders, it has never proved satisfactory with regard to discs. The obverse impressions of the original matrix are called "mothers" in the trade, in view of their office in reproducing matrices from the "master."

A further method, and one still in extensive use, is the simple one of silvering the master matrix. In this case the need for nickel plating or steel facing the original is removed; and many practitioners avoid the plating process altogether in the case of the master matrix. This is to be deprecated, because, although the absence of this thin film of foreign metal, which in the case of phonocut tracks will microscopically change or vary the sound wave modulations and affect the character of the tone when it is subsequently

reproduced as a record, there are likely to arise many worse results through the corrosion of a copper surface. It would be probably better to gild the surfaces of disc master matrices, as in the case of cylinders. For the needle discs, having a sinuous track, the same precautions need not be taken, as a thin film of covering metal may be highly polished without any fear of changing either the amplitude or the form of the sonorous markings.

After plating the master matrix with silver, as referred to, a solution of iodine in methylated spirit should be covered over the record surface. When the spirit has evaporated, this medium acts as graphite acts in general electrotyping by permitting the easy separation of the two surfaces. The back of the matrix should be stopped out with varnish or paraffin wax to prevent the deposit from enclosing the matrix like a shell. It should be rinsed before immersion in the copper bath. When the deposition is completed, it can be readily removed from the silver surface of the original negative, when it will appear as a positive record in copper. From this practically any number of working negatives may be obtained by repeating the above process.

The double cyanide of silver and potassium, dissolved in water, is the best working solution. Ordinary commercial silver, with copper alloy, works satisfactorily. Two and a half ounces of the metal should be present in each gallon of the solution. The method of reducing the metal is disagreeable, and the nitrate of silver is best procured ready prepared. Dissolve one ounce of this in each gallon of distilled water. Prepare also a similar bulk of solution, in which four to six ounces of the potash salt enters. Add these, with constant stirring, until a precipitate of cyanide of silver ceases to fall as a white powder. The liquid must settle to clear. The clear liquid should be poured off and more distilled water be added with rapid stirring. Again leave it to settle, after which pour off in the same way as before. The washing may be done several times as long as the silver is not lost in the process. Next make another solution of cyanide of potassium (about one ounce to the pint) of half a gallon to each ounce of silver cyanide, and add it to the latter with continuous stirring until the salt is dissolved. Then dilute the whole to about half-a-gallon to the ounce of cyanide, with distilled water, adding about one ounce to the gallon of potassium cyanide to form free cyanide, and to enable the anode to be freely attacked. A small addition of bisulphide of carbon will give the deposit a very bright surface, but more current will be required, and great caution must be observed in putting it into the solution, which must be done gradually, or the whole bulk will be rendered useless.

The anode must be pure silver, as large in its surface as that to be deposited. Motion should be given to the matrix to be plated to ensure uniformity of deposit. The specific gravity of the solution should not be lower than 1·042 nor a great deal higher. The surface will probably require polishing when deposited. A more simple solution for depositing silver consists of two ounces of cyanide of potassium to the gallon of water. Silver requires a greater current pressure than copper, or the anode may be arranged nearer to the cathode. The number and variety of silver solutions are so many that the reader is referred to the excellent handbooks which deal with them with far greater thoroughness than space will permit here.

In concluding the remarks upon the making of matrices, it may be useful to point out that the most common difficulty encountered by workmen in the deposition of copper is the variable quality of the deposited metal, which makes its tensility uncertain, notwithstanding that the strictest attention may be paid to the specific gravity of the solution, its thorough diffusion, and to the tension of the current passed into the bath. The chief, indeed the only, cause of this occurrence, when other things are properly in order, is the weakening of the acid in the solution. It is of the utmost importance that the relative proportion of acid to the bulk should be maintained. This is generally understood, but it is not so generally known how to determine the ratio of free acid in the solution after use, but this may be done by titrating the copper solution with normal soda solution, Congo paper being used as an indicator. By means of a pipette, bring 10 cubic centimetres of the copper bath into a beaker glass, dilute with the same quantity of distilled water, and add drop by drop from a burette normal soda solution, stirring constantly, until the Congo paper no longer is coloured blue when moistened with a drop of the solution. The cubic centimetres of normal soda solution consumed multiplied by 4·9 give the number of grammes of sulphuric acid in the litre (61·028 cubic inches).

CHAPTER XII.

THE PRESSING OF DISC RECORDS.

The up-keep of a pressing plant is a very expensive item, and only the largest record manufacturing firms employ presses of their own. In the early days of the disc trade almost the whole of the pressing in Europe was done in Germany. Plants were early set up in the United States, and at least one firm in England set up extensive works to press records for the trade. Others have followed in later years, and in this respect the model factory laid down by Mr. Hough at Peckham is very complete and well organised. The reduction in the prices of disc records in recent years has made it more and more incumbent on manufacturers to include pressing, and so save the profit to another firm which would inevitably be lost otherwise. The companies which contracted for the pressing of records from supplied working matrices certainly facilitated the business, the record composition being included in a stated charge. Manufacturers always knew the actual cost of this most important item, and could calculate their respective costs of production to a nicety.

The presses employed for this work are variously designed, but are all the same in principle. A common type is illustrated in Fig. 35. They are invariably operated by hydraulic power, and are furnished with cooling chambers against the plattens, with means for the circulation of water. In the factory they are usually placed in rows, with steam

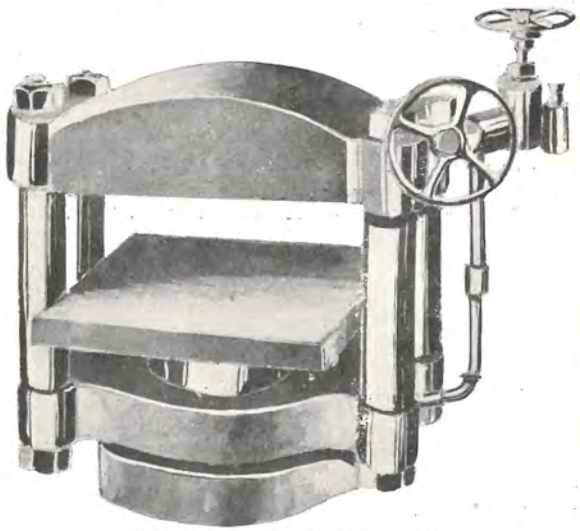


FIG. 35.—A DISC RECORD PRESS.

beds adjacent, for the heating and manipulation of the record material. Fig. 36 shows a group of presses and steam beds installed for work.

The composition employed for the record itself consists of variations of shellac, barytes, china clay or Fuller's earth, with cotton flock,

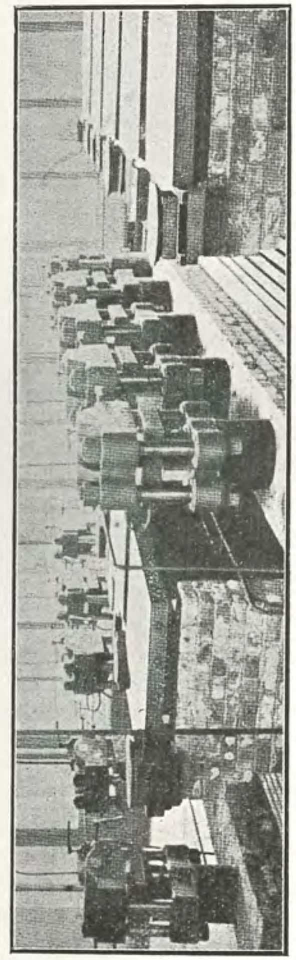


FIG 36.—A GROUP OF RECORD PRESSES.

finely dessicated,—for binding. Sometimes dessicated asbestos is used, as well as other similar substances, in place of cotton, as the latter has certain drawbacks. Usually, the composition is homogeneous and is pressed in the manner that electrical insulating blocks are pressed. Another method, however, consists in utilising waste material between two thin sheets of rice paper coated with pure shellac. The whole is amalgamated by pressure, and the result is a very bright and clean surface.

The first operation in pressing is to knead the composition on the warm bed plates (steam heated) and divide it into lumps like patties, approximately in size which experience has shown to be sufficient, and not more than sufficient to produce a full record when pressed flat. About half a pound of ordinary material is sufficient for a ten-inch disc of average thickness. The *modus operandi* is as follows: the dies, with the matrices fitted therein, are well warmed on the bed-plate at the same time as the material. In double-sided record pressing, there is a pair of steel dies each fitted with a matrix, the under die having a pin projecting through the matrix to engage in a corresponding recess in the upper die. The paper label, which serves to indicate the title and number of the particular record, has also a hole in its centre, and it is placed face downwards against the matrix in each case. The pin serves to keep the label central. This

done, a lump of composition is next placed in the centre of the matrix and covering the back of one of the labels. The second half of the die is then brought into contact with the material, the whole being boxed in, as it were, ready for the press. The dies, of course, are furnished with stops to ensure the desired thickness in the record. By the application of the power the ram is slowly set in motion, upwards, to effect a squeeze between the dies, which, however takes but few seconds to effect. The superfluous material is squeezed out between the edges of the dies, apertures being made for that purpose. The circulation of the cold water through the press soon chills the impression, and the waiting time is usually occupied in preparing the next record for similar treatment. The work is thus continuous, as the records are best released from the dies whilst yet warm, after some amount of cooling. It will set much more rapidly when released from the still warm dies, as long as it is laid upon a flat surface to do so, which is important to remember.

After this operation is finished, the record is transferred to a trimming machine, which clamps it between two slightly smaller, felt-lined discs, in juxtaposition, on spindles, for the purpose of being trimmed clean at the periphery. This is done by means of carborundum and finally polished by friction.

The work of pressing records is comparatively slow, when the far more rapid process of moulding wax cylinders is considered. A workman pressing, say, an average of 250 records per day is considered a good man. This work is usually done by piece work, and the conditions of working are anything but pleasant, the work being heavy and the atmospheric temperature oppressive. A good number of presses will be required to be at work together in order to give the output necessary for a first-class firm, say, a minimum average of 50,000 records per week during the season

Shellac, being an essential ingredient of record composition at present, is likely to rise higher and higher in price, which will prevent great reductions in record prices in the future, after these reductions have reached the minimum profit stage. Other substitutes will very likely be discovered, but this has been a difficulty so far.

What appears to be a matter of trifling moment, and yet one worthy of consideration by all manufacturers, except "stencil" record makers, is that of the paper label which is pressed into the centre of the record. I have no doubt whatever that thousands of pounds a year might be saved to manufacturers by dispensing with these altogether, and by engraving on the matrix all the necessary particulars, subject title, etc., which would appear in the subsequent pressings. Messrs. Pathé Frères were the first to adopt this method, if I remember aright; and the beautifully embossed design more recently adopted by Mr.

Edison upon his equally beautiful discs is evidence of progressive policy. It is not so much the cost of the paper labels which counts, although these are usually done in an artistic way and are comparatively expensive, but what happens in practice, with a large variety of records to be pressed, is that wrong labels often get attached to the records, and this circumstance not only renders the records commercially valueless, but the difficulty of removing the paper from the material, before it can be used up again, is very considerable. If the matrix itself bore its own title, no mistake could possible arise, and if a defective impression occurred (which also frequently happens), the material would be ready at once for employment again.

CHAPTER XIII.

THE MOULDING OF CYLINDER RECORDS.

The commercial moulding of cylinders is a far more rapid process than that of pressing discs. The matrices are provided with bases, and with flanged extensions attached to their upper ends, and these two parts are provided with extending lugs or similar means to enable rods to clamp the whole together. The object of the flanged head is, when dipped into the wax vat, to hold a quantity of superfluous wax, which, cooling, shrinks considerably. A core is generally furnished to the mould, which is screwed into the centre of the base plate, and provided, at its upper end, with a long metal rod or handle for the convenience of lifting the mould in and out of the molten material. The substance generally used for moulding cylinder records is a composition whose base is sodium stereate with which oxihydrate of alumina is incorporated, and to which is added about 50 per cent. of black mineral wax, which is sold cheaply as a commercial article and in which ozokerite or asphaltum largely enters. It is preferable to add, also, a small proportion of Canauba wax, which furnishes a tough and smooth surface; and although this was pretty freely used some

years ago, when the higher prices of cylinder records permitted its adoption, it has been discarded in later times on account of its relatively high cost.

It is usual to employ very large vats, heated with gas jets, in the preparation of the composition, so that a large quantity is available as required, and the composition is transferred from the vats to the moulding tanks by any convenient method. The latter are comparatively shallow, but allow of a large number of moulds being placed in them at the same time. The tanks are maintained at an uniform heat, and as the moulds get sufficiently hot they are lifted out and cooled by the effect of the colder temperature; or, by another arrangement, are facilitated in their cooling by means of an air blast. Still another plan has been resorted to with some success, which is to plunge the mould into a shallow bath of cold water, which gradually but quickly cools the wax composition. Care should be taken not to chill the wax too suddenly, or the record may be split, but the more rapid the process of chilling, with this precaution well in mind, the more brilliant will be the record surface, presenting a lustrous appearance as well as being finer in superficial texture.

A method of moulding patented by Mr. Edison is illustrated in Fig. 37. The tank is arranged so that the matrix, with cover and plunger, fits upon a cylindrical chamber forming a part thereof, the molten wax being allowed to enter the cylindrical chamber by orifices near the bottom. The plunger has the core attached, or, to be more precise, the core forms part of the plunger itself with a rim at the base to carry up the wax into the matrix above. The scheme has everything to recom-

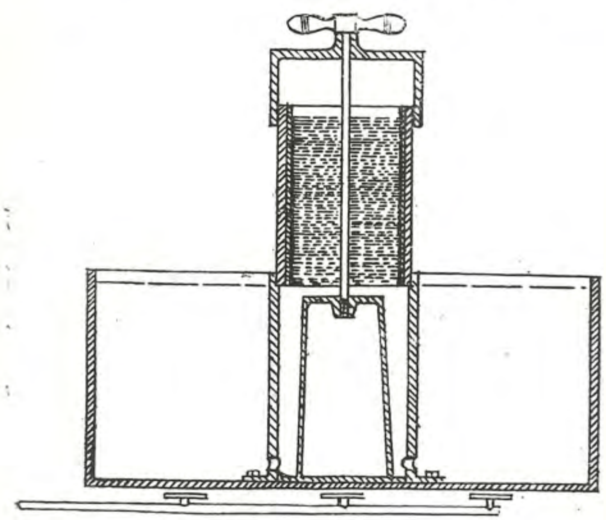


FIG. 37.—EDISON SYSTEM.

mend it on the score of cleanliness and easy manipulation, but its defect is want of provision of means to heat the matrix in order to avoid the presence of air bubbles. Even though such means were provided, the alternate heating and cooling of the mould must occupy

considerable time in the process, which makes any economical advantage doubtful.

A later, but not a highly successful practice, is the moulding of cylinders by spinning. The matrix is gripped in the chuck of a lathe or similarly constructed machine, when the molten wax is conducted to its interior from the outer end which is provided with a flange. The centrifugal force of the revolving matrix has the effect of thrusting the wax against the face of the matrix with considerable pressure. It is a far more economical method, and the possibility of air bubbles near the surface is eliminated, a circumstance which has given rise to much trouble in ordinary moulding in not allowing the necessary time to heat the moulds to the wax temperature. In addition to these advantages, the wax is close-grained and the record is more durable. But the film of air, which is never driven out by the effect of the hot wax against the cold matrix (in spinning) is often quickly converted into moisture, and the presence of this condition is to render an otherwise smooth record rough in the surface, which is extremely undesirable. Instead of forming as air-holes, as in the case of moulding, and being eventually driven off by increased heat, this air film remains uniformly diffused and is instantly sealed by the rapidity with which the matrix surface is covered with the composition in the process of spinning.

After the moulding, by whatever method, is effected, the moulds and their contents are cooled, and the metal cores (if used) must be extracted before the cooling has proceeded too far, or they will not be extracted at all. The contraction of the wax composition naturally takes place towards the centre, and the effect of this is to grip the core very tightly. The bore should be tapered, of course, to facilitate extraction. The matrix should next be released from the caps (base and flange-

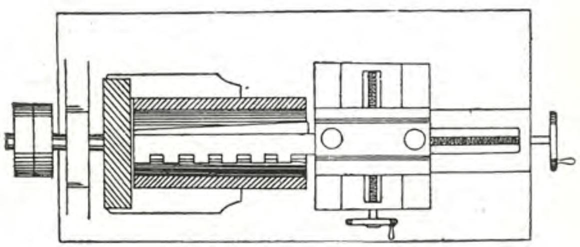


FIG. 38.—PLAN.

head) and inserted in extending jaws of a lathe chuck (or what is the same thing in principle—a boring machine); a slotted tool (see Figs. 38 and 39) is adjusted to the correct mandril taper, and inserted inside the cylinder to the correct position, which is determined by a "stop." The mandril is revolved and the tool is then brought over against the wax interior by the compound slide rest to which it is fixed. The first motion will make the bore of the correct taper to fit the mandril of

the reproducing machine, while a subsequent lateral motion, determined also by a "stop," will produce the concentric rings which are to be seen inside the bore of cylinder records, and which serve as a better means of grip for the record on the mandril. Machines specially constructed for boring, having, in principle, a lathe head, a tool holder with a double slide motion, are invariably used in the factory, as the position of boring or reaming

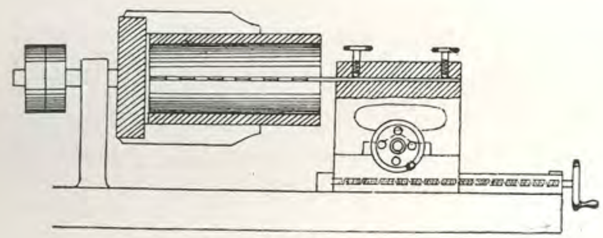


FIG. 39.—ELEVATION.

tools, once ascertained, may be permanently fixed, and their extent of traverse limited, by means of the aforementioned "stops." Boys or girls can operate these machines very rapidly, under these circumstances. The experimenter, who is not governed so much by considerations of speed, can do the work just as efficiently with a lathe.

When the bore is completed, which at high speed rotation takes only about one minute to do, the matrix and record may be released from the chuck and stood aside to cool until the record shrinks away from the matrix. The latter should then be carefully slipped off the former. The surface of the record may be easily spoiled in doing this, if great care is not exercised.

When the record is thus free from the matrix, it is ready to be put upon the trimming machine (again, a lathe in principle). A spindle holds a short mandril in the centre such as was described in connection with shaping of cylinder blanks, and one end is gripped by the chuck while the other—after the record has been put on the mandril—is run in contact with the tail-stock centre. Only the superfluous wax at the head of the record requires cutting off and finishing, which is done in a few seconds with a sharp tool as the record revolves. The other end, it will be remembered, was moulded clean by the overturned matrix end containing the engraved title, number and make of the record.

The record is now finished, with the exception of filling in the incised letters and figures, etc., on the end with a white paste. This is made, mostly, of common whiting and size, but sometimes of carbonate of lead and gum. With a small pad it is smeared well into and over the lettering, and when quite dry, the record may be re-mounted on the trimming mandril once more and be carefully skimmed with a smooth blade over the superfluous white paste, until the lettering is seen to be well

defined. Or the record may be wiped with a damp flat pad to remove such superfluous paste as may exist, when the lettering will appear white in contrast to the body of the record, which is usually black in colour. This operation completes the process, and the record is ready for finally testing, to discover any possible flaws in the moulding. After which, if it is found to be free from mechanical defect, it is put into the wool-lined box with which everyone is familiar, and is properly labelled, and is passed on to the store-keeper, who in turn passes it on to the factor or dealer, who distributes it to the public.

CHAPTER XIV.

INDESTRUCTIBLE RECORDS.

The moulding of cylindrical records in celluloid, or cellulose compositions, is an altogether different process, and requires very different appliances. Instead of the composition being rendered fluid like the wax, a celluloid blank, which is merely a comparatively thin celluloid tube, shaped at either end to form a perfectly steam-tight joint, is inserted in the matrix, and after being closed by suitable ends, or caps, is softened and printed by means of a jet of steam under pressure. When the printing has been effected, which occupies about two minutes, according to the substance of the tube and degree of steam pressure, the steam supply is cut off, and a jet of compressed air at about the same pressure takes the place of the steam, in order to chill and fix the softened celluloid against the matrix face and prevent its collapse in the interior of the matrix.

The first patent to be taken out in England for the making of celluloid records was by Mr. John Lewis Young in 1894. The patent specification, however, discloses no effective means for the practical working out of the process, but the idea of celluloid cylinders appears to have been originated by Mr. Young,

pressed by means of an electrotyped matrix of an original wax record. The subsequent application of an electrotype matrix for moulding cylinders entirely revolutionised the cylinder record manufacture and marked an extraordinary advance in the duplicating processes.

A number of patents were taken out by different inventors which embodied minor differences in mechanical means to accomplish the same end, and always with a view to technical or commercial improvement.

Woolcott's process (Patent No. 15,057 of 1899) embodies a tube of *plastic* material such as celluloid (softened on the outer surface by such means as acetone) to be embedded between a matrix and a circumferentially recessed metallic piston which might be pressed by any fluid medium against the inner wall of the blank. The idea was crude, but it must be remembered that it was one of the earliest attempts to procure records in hard material and by pressure, in contradistinction to moulding in fluid materials.

The Lambert process was apparently the first working patent, although it is doubtful whether the success achieved by the Lambert process was in reality due to the strict application of the patent claims. In any case, the scheme was unnecessarily cumbersome, and has since passed out of date. The blank was placed upon the base of the press which acted as a closed end to the cylinder chamber. See Fig.

40. In order to seal the upper end of the chamber, a removable cap was furnished, upon which a gear spindle was allowed to drop. A weighted lever mounted on a shaft and

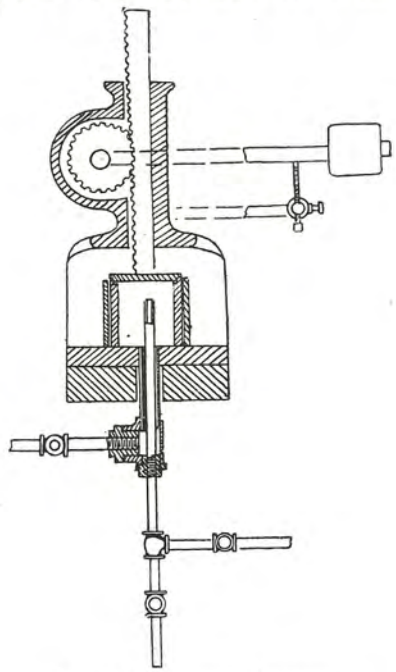


FIG. 40.—LAMBERT PROCESS.

carrying a pinion meshing with the spindle referred to, enabled the pinion to raise or lower the spindle as required. In principle, it was a sort of safety valve, but was designed

to adapt the upper cap to the edge of the celluloid tube to ensure a steam-tight joint, as the latter became affected by the application of steam heat. A screw was provided to limit this movement so as not to crush the blank or otherwise put it out of proper position.

Steam was next forced into the chamber thus formed at a pressure of about 30 lbs. to the square inch through a conduit leading from the boiler to the press. The steam was confined in the chamber for a short time at an uniform pressure, and to prevent condensation was allowed to blow from an exhaust pipe which surrounded the supply pipe.

The steam, being kept at substantially uniform pressure, softened the blank and forced it out against the inverted record of the matrix. A positive duplicate of the original record was thereby obtained in plastic celluloid. When the pressing was thus accomplished—and experience alone determined what length of time was required to effect this—the steam was shut off and air under pressure was admitted into the chamber, which fixed the record on cooling. The air being subsequently shut off, the record was removed from the matrix—the slight contraction of the celluloid in cooling enabling this to be accomplished with comparative ease, particularly if the original blank of the record, from which the matrix was obtained, instead of being shaved or surfaced cylindrically, was made to assume a slight taper. The record film was then ready for mounting or filling with a *papier mache* tube, or plaster of Paris, to give it solidity, and to perfectly adapt it to the standard mandril, which is tapered, of the reproducing machine.

Really, the most important process in the practical manufacture of cylinder indestructibles, and the missing link, as it were, of the Lambert process, was that patented by Mr. W. F. Messer, in 1902. With the use of higher steam pressures (up to about 60 lbs.) for the purpose of effecting an economy in time, the disposition of the steam to escape at the ends forming the joints was very great, and a large percentage of spoiled records resulted. It occurred to Messer that this escape might be diverted so as to effect a more rapid sealing of the pressure chamber. He therefore provided the upper cap and the base of the chamber with small perforations, the effect of which was to allow the rush of escaping steam to force the softened celluloid ends into the perforations and thus effectually close up the avenues of escape. Although Messer did not quite perfectly solve this minor but very important problem, he came very near to it, and enabled records to be duplicated with far less waste and in a shorter time than was before possible. For an illustration of the system, see Fig. 41.

Probably the best method of mounting celluloid cylinders was invented by Petit in

1902. The great tendency of celluloid to shrink, by the atmospheric action upon its camphor element, and therefore of the records to undergo a variation in diameter, becom-

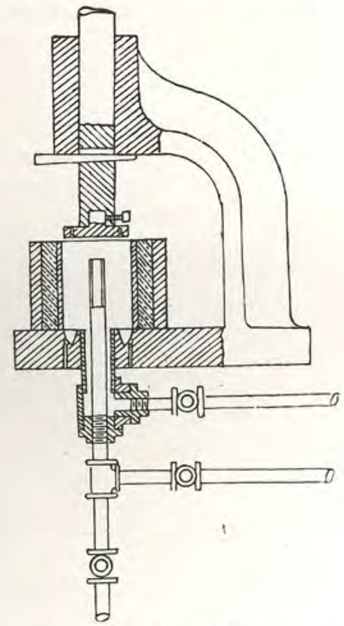


FIG. 41.—MESSER'S PROCESS.

ing a source of much annoyance to users, was a problem which beset makers, and one which Petit effectually solved. I have had celluloid records made by his process for several years and under various temperatures, but have never known them to vary their shape, a fault common to all other celluloid records. His method consisted of clamping the inturned edges of the record with metal rings, in the process of pressing the records, one slightly larger than the other in the inside measurement, and which formed a correct bearing for the tapered mandril of the reproducing machine as well as making the record bore concentric with the outer surface, so essential to correct tone. It became a simple matter to subsequently fill the interior of the record with plaster of Paris, to give solidity of tone and stability of character to the same, as the annular rings served as a correct gauge for skimming away any superfluous plaster of Paris, and as a quick and easy method of mounting. By the use of plaster of Paris, the annular as well as the longitudinal contraction of the celluloid was thereby prevented.

It is really astonishing what a great improvement in celluloid records is effected by mounting, or re-inforcement, as it is sometimes decribed. Plaster of Paris backings have proved to be the best of all, and moreover it is the easiest possible method, in conjunction with the Petit process. It is better to employ an equal admixture of plaster of Paris and Parian cement, so that the setting does not take place too rapidly. Other alternatives have been applied, notably tubes of compressed strawboard, *papier mache*, and the

like, but these have invariably proved to be failures, as the power of contraction possessed by celluloid is sufficient to distort all such materials which are possessed of an inferior tensile strain.

In addition to the improvement effected by Petit in furnishing the inturned ends of the cylindrical record tubes with overturned metal

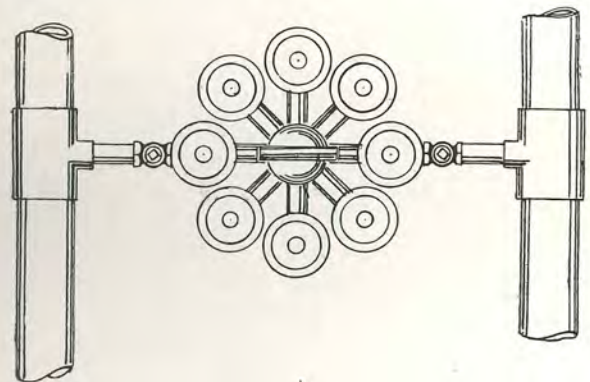


FIG. 42.--PLAN (PETIT'S PROCESS).

rings to obviate eccentricity in rotation upon the reproducing mandril, he introduced in 1903 an economical arrangement of presses of more simple form than those of his predecessors. The plan and elevation views of a group of eight of such presses, operated simultaneously, are shown in Figs. 42 and 43.

The before-mentioned difficulty of obtaining a steam and water-tight joint in the operation of pressing celluloid records—to obviate moisture creeping between or forming within the exterior celluloid blank surface and the matrix face, was got over by Petit by the introduction of rubber cushions formed as rings, and which were arranged to sit between the edges, supported by flanged collars. A screwed sliding

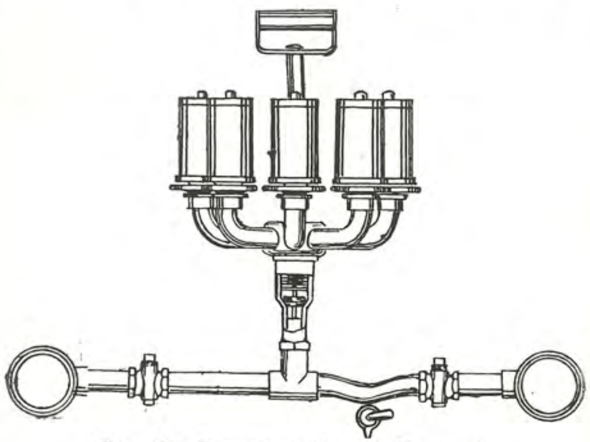


Fig. 43.—Elevation (Petit's Process).

movement to the spindle brought the rubber rings into firm contact. After the blank had been subjected to the usual steam and air pressures as required, the cocks were shut off and the presses were unscrewed from the base and immersed in cold water to further cool the matrices for the purpose of facilitating the extraction of the records.

Whilst giving due credit to the aforementioned inventors for the real improvements made in the production of records in celluloid up to this period, it must be frankly admitted that there was yet much to be done before they could hope to successfully supercede the older wax records, notwithstanding their greater durability and augmented volume of sound resulting from their denser surfaces. They were extremely harsh in tone, and surface noises were almost as prominent as those of the average disc record. Many devices were resorted to in order to tone down and reduce these objectionable features, which almost invariably succeeded in reducing the tone-quality of the records as well, and so nothing was gained. One company after another went under in attempting to oust the wax record, and for a time the latter held sway. One could scarcely be surprised at this when we remember the beautiful standard records in wax which Mr. Edison had, during all this time, been engaged in perfecting by the best known processes, and which had got a firm grip upon the public patronage.

Without being in the least discouraged by other people's failures in the production of records in celluloid, I set to work in 1904 on a series of experiments designed to overcome their mechanical drawbacks. It would be too long and tedious a story to go through these experiments in their order, for I found that I had to go back to the beginning many times over before I reached the culmination of my object some two years later. But to summarize, I may say that I found it necessary to use hard, close-grained blanks for recording, which could be warmed just before use, and which would afterwards present the finest surface possible to be obtained, upon contraction by cooling. The next important thing was close deposition in the bath, in procuring the metallic negative, and this was only to be obtained by comparatively high tension current, with suitable motion given to the record. I experimented with various grades of celluloid material, and found that most of them were charged with all sorts of foreign impurities, which made the production of a comparatively noiseless surface difficult if not impossible to secure. Some samples I had from the Rhenish Company, in Germany, proved to be the best obtainable, and were very homogeneous on the whole. When all the conditions were right, I found no further difficulty in producing celluloid records as mellow in tone and as noiseless in surface as the best examples of Edison wax records. I engaged with a London Company to manufacture and put them upon the market, and fitted up a factory with the necessary machinery in furtherance of this project early in 1907, but owing to financial and other disagreements, I abandoned the enterprise and nothing came of it except ruinous litigation in the High Court

Mr. Edison had about this time introduced the 200 thread-to-the-inch cylinder in hard wax composition, and I saw at once, from results obtained, that such a type of record was, from all points of view, eminently suited for duplication in celluloid. I lost no time in making samples of such records, and had a number of subjects ready in 1908. I publicly stated that the wax "Amberol" was doomed as a mechanical failure, and that it would be entirely superseded if it were duplicated in celluloid, which subsequently proved to be the case, when Mr. Edison introduced the "Blue Amberol." As the most perfect specimens in sound reproduction that have yet been brought forward, these later achievements of manufacture take a high place.

In my earliest experiments in manufacturing celluloid records I found that record matrices of about 1-16th of an inch in thickness would withstand a tensile strain of some 200lbs. to the square inch. And as no such pressure was ever required to mould plastic celluloid I employed the simple matrix as one part of the composite press. This effected great simplicity in press construction, and favoured a scheme I devised for the sudden chilling of the matrices. The texture of celluloid or cellulose compositions is considerably porous, which accounts, in some measure, for the noisy surfaces of pressed records, unless specially treated. I found that when sufficient time had elapsed for the record to be printed by the influence of steam pressure, an excellent means of closing the surface grain of the material lay in suddenly chilling the matrix whilst under steam pressure and just prior to the introduction of compressed air, in contradistinction to the older method of cooling from the interior of the tube exclusively. I thereupon arranged presses in a group of six, built up on a main supply pipe, one end of the latter being provided with a free union made steam tight, the other with a closed end, engaging freely with a trunnion support. By means of a handle, the whole of the six presses might be turned over into a tank of cold water at one operation, the effect being to quickly cool the matrices from their heat absorbed from the steam, and by such means to set the faces of the records at once. The design of press and immersion arrangement is set out in Russell and Jung's patent, No. 14,073, of 1907.

It is possible, of course, that celluloid records may sometimes emit unpleasant surface noises, even though they are manufactured in the manner described. It should be remembered that the pressing is only one of a series of operations, each of which should be very carefully performed. If, for example, the shaving or surfacing of the original wax blank is improperly done, a certain roughness will be apparent throughout the rest of the processes, even though these are carried out with the greatest degree of skill. Or, again, if

the wax record is perfect in every way, the matrix may be badly done, and the roughness will originate at that stage and be carried through the pressing. The number of really skilled depositors, capable of making perfect matrices, is few and far between. Many of the leading companies entrust this high class of work to ordinary electrotypers, who work by rule of thumb and who know next to nothing of the exactness required by the most modern methods of chemistry and electricity. Not understanding how to deposit fine surfaces, they generally resort to artificial polishing of the matrix face to produce a brilliant effect to the eye, and frequently succeed in disfiguring the character of the record itself. A large proportion of inferior records presented to the public have been ruined in this way.

In considering the behaviour of celluloid in record moulding, it must be borne in mind that although it is a most excellent material for moulding purposes, it is a composite body, the elements of which are not chemically combined, although it presents, on analysis, a rare example of close mechanical mixture. Celluloid is formed by dissolving nitro-celluloses (such as gun cotton) under certain conditions, in camphor, or its chemical substitute. Phenol is used as a substitute for camphor very considerably, as may be easily determined by dissolving celluloid in boiling caustic potash.

Celluloid becomes plastic if heated to about 125 degrees C., and may be readily moulded by the application of a moderate pressure. If it is desired to make cylindrical record blanks from the sheet, the shaved edges may be joined by coating the two surfaces with collodion and applying the requisite pressure. The manufacturers of celluloid, however, generally supply the material in tube lengths for the purpose of phonograph blanks, which can be cut to the required sizes.

Dr. Fr. Boëkmann, in his work on "Celluloid," furnishes some useful hints in analysis. He says:—"Mineral adjuncts can be detected by treating the finely rasped or shredded celluloid with ether, chloroform, or other volatile solvent at a moderately warm temperature. Under this treatment magnesia, ammonium phosphate, lead borate, or other ingredients are left behind, whilst nitro-cellulose (gun cotton), camphor, fatty oils or paraffin wax pass into solution. The examination and determination of the insoluble residue is performed on the ordinary analytical lines, though some difficulty is interposed by the organic compounds latterly employed instead of camphor. The examination of the solution is rather difficult, but the nitro-cellulose can be determined by converting it into ordinary cellulose by means of reducing agents. If nitro-cellulose be treated with a concentrated solution of ferrous chloride and an addition of hydrochloric acid at 100 deg. C., nitric-oxide gas is evolved, the precipitated iron hydroxide is redissolved in the hydrochloric acid, and structureless cellulose is left behind. According to Hadow, a similar reduction is effected in the case of gun cotton by treatment with an alcoholic solution of sodium sulphydrate, the precipitated cellulose being then carefully washed with alcohol, dried at 100 deg. C., and weighed. The determination of nitrogen in celluloid can probably be effected by the method employed by Walter Crum for the nitrogen of gun cotton. A weighed quantity of gun cotton is heated with an equal quantity of concentrated sulphuric acid in a tube filled with mercury. The reaction liberates nitric acid, which acts on the mercury, and oxidizes a portion of the same, nitric oxide gas being given off. After the reaction has continued for several hours, the volume of the nitric oxide gas is read off in the graduated glass tube, and a solution of ferrous sulphate is added; this absorbs the nitric oxide gas, the amount of which is indicated by the shrinkage of volume in the tube."

It has been found that celluloid for records is better if not used too early after manufacture. It should be stored in a dry place for a month or two. If allowed to stand too long out of use, on the other hand, the evaporation of the camphor or volatile substitute will cause it to be brittle, when the turning of the ends of the record blanks will become difficult. It will also require more heat to soften, and more pressure to print, than newer material. In such an emergency, it will be well to bear in mind that celluloid may be restored in some measure to its original flexibility or mobility by being dipped for a short time in spirit of camphor.

The objection to celluloid records that they are easily inflammable is not well grounded. Almost invariably the material supplied for phonographic records is a composite substance. It is seldom that celluloid is employed in its pure state. A very good composition was made by the French Celluloid Co., of Paris, under the patent of Mons. Defavrie, consisting of celluloid containing a small proportion of stearic acid which was added when the celluloid was being softened by treatment with alcohol. I have worked a considerable quantity of this composition with excellent results, and have found it far less combustible than pure celluloid. I have noticed also that an excess of steam heat will sometimes separate the stearic acid and cause it, or some portion of it, to be driven to the surface, but with reasonable care this can be easily avoided.

There have been many ingenious attempts to manufacture celluloid of an entirely non-inflammable character, but they have been more or less failures. The introduction of ingredients to effect this object, so antithetical in nature, has generally rendered the substance inferior for all the purposes for which it is so eminently fitted. Perhaps Stocker's is the best yet reached. The mass prepared by him possesses all the important properties of nitro-cellulose—transparency, toughness, and perfect

plasticity by the application of heat while it can only be ignited with considerable difficulty. His method is to treat the finished celluloid with an addition of stannous chloride which enters into molecular combination, and a homogeneous mass results, which will burn only when held directly over a flame, and ceases to do so the moment it is removed.

The tubes of celluloid or celluloid composi-

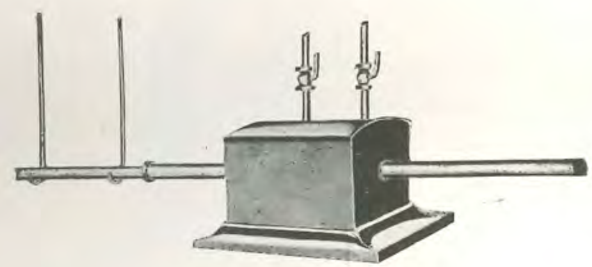


FIG. 44.—STRETCHING CELLULOID TUBES.

tion which manufacturers supply for phonograph blanks are generally made in lengths of several feet, and they not only require to be cut into the exact lengths for the records, but firstly to be mandrilled into the cylindrical form of the correct diameter to suit ordinary reproducing machines. The mandrilling is performed by a machine, or rather, by means of an apparatus designed to force the lengths over a short steam-heated mandril, after which it will set immediately. An illustration of such apparatus is shown in Fig. 44.

When this operation is completed, the correct lengths are cut by an ordinary fine cir-

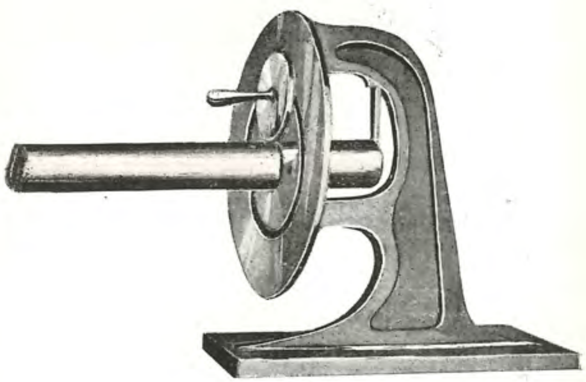


FIG. 45.—CUTTING CELLULOID.

cular saw, or by a revolving steel cutter as represented in Fig. 45.

The lengths so cut are required to measure more than the actual length of the finished record, on account of the shaping of the inturned ends. The shaping press (steam-heated), when operated by the lever handle,

brings down the celluloid cylinder end against the warm metal flange which forms the mould for the inturned end, and which requires some mechanical force to assist the moulding, not being enclosed. (See Fig. 46.)

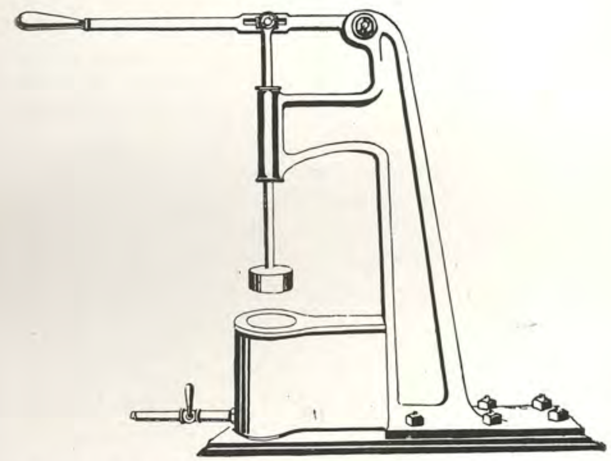


FIG. 46.—PRESS FOR TURNING ENDS OF CELLULOID BLANKS.

The desired shape of the end once secured, the tube can be released from the warm metal, when it will set and keep its shape with very little contraction. To turn the reverse end, it is only necessary to repeat the process, after reversing the tube ends. The blank is thereupon ready for moulding a record from the matrix.

If polishing the surface of the blank is considered necessary, before pressing the record—and I have found it advisable when done by friction alone so as not to impart foreign impurities into the surface—it may be done in the ordinary way by means of a high-speed buff on a polishing lathe. Some makers polish by pumice powder with water, following with tripoli and an admixture of oil, and finally finishing with a swansdown mop and Sheffield lime. I have no doubt that the effort to so secure a smooth and theoretically noiseless surface has been responsible for much of the harshness associated with indestructible records in the past. But care must be used in the exercise of simple friction for polishing, as the heat engendered, if excessive, will similarly defeat the object in view and give rise to "clogging," which will certainly not favour the formation of an ideal surface. If the material is in good condition and is properly pressed, the polishing may be entirely dispensed with to advantage.

In the construction of the matrix press for the final printing of the record, the upper metal cap which forms the head of the matrix-chamber should be provided with an annular boss on the interior around which the inturned end of the blank should fit tightly. At the extreme point of this boss several small perforations should be made to allow steam to

escape until the celluloid blank has been softened to a sufficient degree to fill them up by the internal pressure. An absolutely steam-tight joint is thus easily obtained automatically. On the outer flange of the cap is usually engraved, negatively, the title or theme of the record, which, when pressed, appears in raised letters on the end of the record itself. Or, by way of alternative, a ring, electrotyped from a similar positive engraving, may be inserted, in a space provided, which, after pressing, will appear as incised or embossed letters, and which may be filled in subsequently with white paste as described in connection with wax cylinder records. The clamping screw of the press yoke should be male centred and adjusted to screw down into a female centre on the outside of the cap.

With regard to the production of steam for pressing these records, a 10 h.p. multitubular boiler will be found to be adequate for the continuous supply at about 100 lbs. per working day of, say, ten hours, making a moderate allowance for waste. Such boilers are furnished with injectors, as a rule, to keep up the supply of water, automatically. The amount of fuel per week to run such a boiler would be about $1\frac{1}{2}$ tons of coke, and something less than that amount if coal is used. Five thousand records per week could easily be turned out with this accommodation, with, say, a score or less of presses constantly in use. The best average steam pressure for the standard cylinder records is 60 lbs. to the square inch, which can be regulated in a simple manner and indicated by a Bourdon or Jackson gauge made for this purpose. The

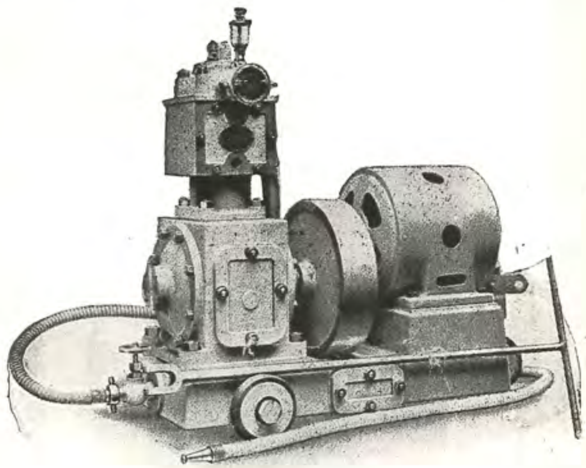


FIG. 47.—AIR COMPRESSOR.

exact length of time for the steam to remain in the record chamber must be a matter for experience alone to determine, as different materials require different pressures. Different substances of the self-same material will also

require a variation in pressure. A good average time I have found to be three minutes or under, after which, and when the steam is shut off, the compressed air should be admitted. The air pressure very naturally should be the same, or approximately the same, as that of the steam. There need be no limit of time for the air to remain in the chamber, as the only object of introducing it is to cool and set the record before it can be extracted from the matrix. But this involves the cooling not only of the celluloid tube, but the matrix also. The water bath I devised and previously referred to affects not only this latter object quickly and effectively, but facilitates the process of extraction enormously, as well as producing a closer surface.

The type of air-compressor, power-driven, which it is desirable to employ, is that illustrated in Fig. 47. This is one of the very excellent single-stage compressors manufactured by Messrs. Peter Brotherhood, of Peterborough. The illustration shows the machine with electric motor mounted on a portable bedplate, the latter forming the receiver. These compressors are also made with fast and loose pulleys, and may be operated from shafting, with steam as the source of power, if desired. I have found the Brotherhood compressors to be very reliable in every way. A tank for water cooling by circulation forms part of the arrangement, and greatly aids the working efficiency of the compressor in producing its maximum delivery. Fig 48 shows a section of the compressor (No. 66

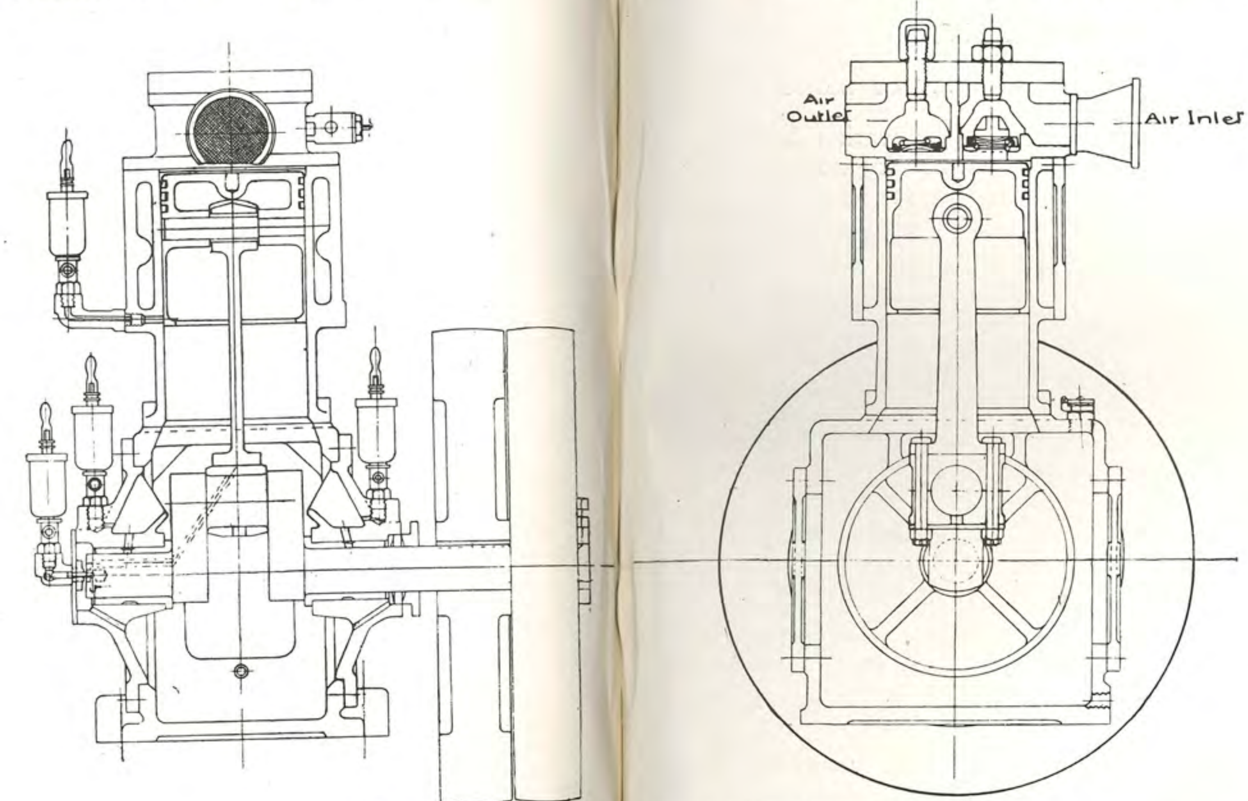


Fig. 48.—Sections of the Single-Acting Compressor.

single acting), which, although much reduced, will serve to explain its construction and

operation, and I should express my indebtedness to Messrs. Brotherhood for their courtesy in sending me the drawing with the liberty to reproduce it.

CHAPTER XV.

RECORDING SOUND BY AGENCY OF LIGHT.

A completely revolutionary innovation has been introduced by numerous investigators in the same field of research, having for its object the making of sound records by photography.

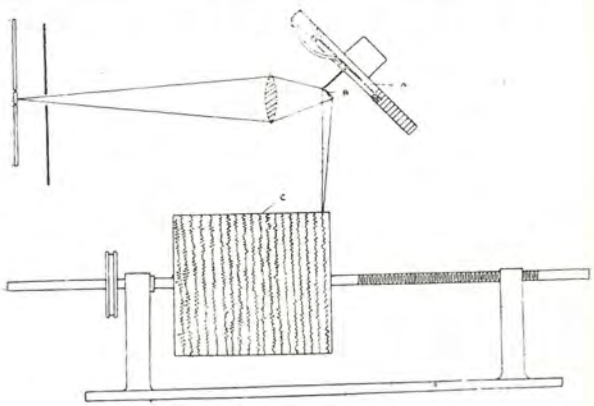


FIG. 49.—PHOTOGRAPHING SOUND.

Quite a number of patents have been taken out in this direction. Foremost in the practical application of the idea was Mr. C. J. Cooke, who secured a patent for an apparatus in 1901, the scheme of which is shown in Fig. 49. A re-

cording diaphragm (a) has a mirror (b) mounted in the centre thereof, and a focussed or condensed beam of light is made to fall upon the latter, which is reflected at right angles on to a protographically sensitive film (c) attached to a drum, which is capable both of rotation and transverse motion in the manner common to the earlier tin-foil machines devised by Mr. Edison. In a modification, two mirrors mounted at an angle are employed, the light being reflected from one on to a stationary mirror and then back on to the second vibratory mirror. The specification provides for the disc as well as the cylinder form of record, and the sensitive films were prepared of bichromatised gelatine, which could be used to produce a negative stereotype or to prepare an etching-resist on a metal surface. The reproduction of the record was effected with an ordinary diaphragm, or could be done by means of the compressed-air relay system. The Provisional Specification refers also to the use of the older chalk reel telephone as a reproducer actuated by the stylus, and also to copying the original records by means of follower and graver stiles for making an etching surface.

An advance was made by Mr. Pletts in 1903. The variations in intensity of a beam of light caused by a vibrating membrane are registered on a sensitive plate and are reproduced by reflecting or refracting a beam of light through this record on to a selenium cell in a telephone circuit (see Fig. 50). A parallel beam of light may be simply reflected from a diaphragm, or to the diaphragm (d2) may be attached a screen (e), parallel to which is another fixed screen. Both screens are furnished with narrow slits perpendicular to the direction of vibrations of the membrane, whereby the intensity of a light-beam emerging through the screens is varied.

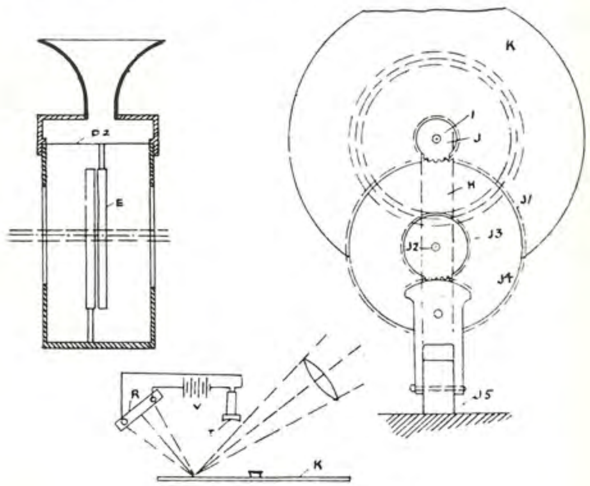


FIG. 50.—PLETT'S METHOD.

The beam is then focussed on to a sensitive plate (k) contained in a dark box. This plate is screwed down on to an axle (i) working in a hinged support (h); or, in the absence of a central hole in the plate, the support (h) is formed with two arms carrying rotating spindles, and both spindles are furnished with pads to grip

the plate. To the spindle (i) is fixed the pinion (j) which is driven from the jack (j4) through the gear wheels (j1 and j3). The support (h) is pulled over on its hinge by an adjustable spring (n), and the combined motion of the plate (k), due to the swinging of the support (h) on its hinge and to the rotation due to the jack (j4), causes the point of light on the plate to trace a spiral path, the shape of the spiral being determined by the gear-wheels and the curvature of the jack (j4). The latter is hinged at (j5) so that it may be thrown out of gear with the wheel (j3) to allow the support (h) and the plate (k) to be brought back into the starting position as required. By these means a permanent record is secured in the form of a line of varying opacity by developing the plate, and the sounds may be reproduced by focussing a beam of light on to a selenium cell (r) in circuit with a battery from an opaque record, as in the lower Figure; or transmitting it through a transparent record on to a selenium cell (r) in circuit with a battery (v) and telephone (t).

A later variation in methods of sound-photography was devised by Mr. William Holden, a patent for which was taken out in the joint names of Holden and Hansard. Mr. Holden entrusted the working model of his apparatus to my care some years ago with a view to further experiment and possible development. The novelty of the invention mainly consisted in substituting an oscillating beam of light for the fixed beam of the earlier inventors which was accomplished by positioning means causing the beam of light to move in a direction non-coincident with the direction of movement of the recording film, the advantage of which is that the whole surface of the film may be utilised and the speed of movement considerably reduced. Thus a ribbon may be recorded in zig-zag fashion to employ every portion of the material, which would be of great value in connection with synchronous cinematographic and phonographic films. The reproduction of the records might be effected, as suggested, by the agency of the selenium cell, which has the property of varying its electrical conductivity in proportion to the degree of light to which it may be exposed, and giving rise to sonorous vibrations correspondingly. The greatest difficulty, however, that has so far attended the operation of the selenium cell scheme, is the microphonic relay, which has proved anything but satisfactory. The infinitesimal resistance offered to a vibrating diaphragm by the photographic system is indeed an enormous advantage in recording methods, but this is completely offset, in the present stage of progress, by the want of a complementary reproducing system.

CHAPTER XVI.

THE TELEGRAPHONE.

In connection with processes for recording sound waves, it will be interesting to recall that ingenious apparatus invented by Valdemar Poulsen, of Copenhagen, called the "Telegraphone." Of all the systems in vogue, this indeed seemed to promise the fulfilment of the most scientific expectations, inasmuch as the usual mechanical drawbacks associated with the earlier cutting and duplicating processes were to all intents and purposes absent. But after many years of experiment it has been found impossible to adequately reproduce the records made upon this principle; and it has, in consequence, like the photophone process dealt with in the previous chapter, been at least temporarily abandoned. In the course of electrical development in the future, it is within the bounds of possibility that someone may discover the missing link.

By the aid of the Telegraphone, the human voice and other sounds are recorded by means of electro-magnetism, upon a coil of steel wire, or, by way of variation, upon a perfectly smooth and thin steel disc, without indentation or visible marking of any kind, and without the aid of any agency other than the mysterious and invisible influence of electro-magnetism. Once made, the record is absolutely indestructible, and can be reproduced indefinitely without the least observable variation; and the further utility inheres in the system that, if it is desired to obliterate a record so made in order to use the wire or disc over again, it can be instantly expunged by the simple application of another magnet. For home recording, and numerous other purposes of commercial utility, the system offers extraordinary advantages, and it is disappointing to know that, up to the present time, the volume of sound reproduced from such records is no greater than that emitted from the ear-piece of the ordinary telephone. Prof. Silvanus Thompson, F.R.S., has borne testimony to the extraordinary perfection of articulation reached by this instrument, but it must be remembered that when volume of sound is not the predominant consideration, it is possible, by the older cutting method upon wax blanks, to produce the most delicate overtones of speech and qualities of timbre.

The ordinary discs in common use are made, in a great measure, to supply a demand for volume, consistent with a fair measure of tone-realism, but this is only possible to be done by augmentation, which is nothing more than a straining after one effect in an *ensemble* of effects, and the consequence is that with every addition of volume *per se* there is a corresponding reduction of tone-realism for the simple reason that while it is possible to increase noise by magnification (as, analogously, it is possible to increase the size of a photograph by enlargement), it is impossible to increase tone-quality in a record, or sharper definition in a photograph, by the same means.

In recording such discs it is usual to employ a simple lever movement, one arm of which is attached to the diaphragm of the recorder, the other being fitted with a sharp triangular style with an acute point, to engrave the record, the fulcrum being attached to the recorder frame. The two arms of the lever are equal in length, and it follows that the amplitude of the sound waves are approximately equal to that of the diaphragm in motion. But when it comes to reproducing these records, we find it to be the general practice to extend one arm of the lever (that part of the sound box stylus-bar above the fulcrum and in direct contact with the diaphragm) to about double the length of the lower arm and needle combined, the net outcome of which is that the two arms are not mutually responsive. An enlarged volume is obtained by this means, to be sure, on account of the abnormal thrust directed against the reproducing diaphragm, but this only means that a greater irrelation has been set up extrinsically between the quality and the intensity of sound, to the advantage of the latter at the expense of the former. The true path to tone-realism is not in that direction.

CHAPTER XVII.

REPRODUCING MACHINES AND ACCESSORIES.

In describing the general principles and construction of instruments for the reproduction of records, I will deal with the cylinder machine firstly, that being the first in the order of development. Fig. 51 represents a model of Scott's "Phonautograph," and Fig. 52 repre-

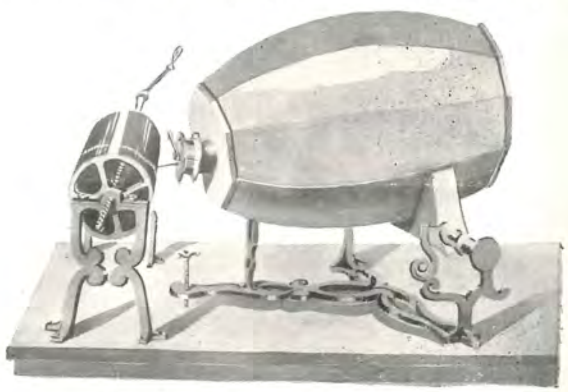


FIG. 51.—SCOTT'S "PHONAUTOGRAPH."

sents a model of Edison's original machine. The construction of both, as far as the mandril and supports and rotating means are concerned, is almost identical, but the methods of obtaining and reproducing records by these machines

were quite dissimilar. The one traced a wavy spiral upon a lamp-blacked surface of the drum, the other indented a surface of tin-foil mounted on the drum. In the latter we first reach the practical application of the former, and the means to mechanically reproduce sonorous vibrations. Mr. Edison automatically registered these vibrations as indentions in the foil. The foil provided sufficient stability to overcome the friction engendered by the

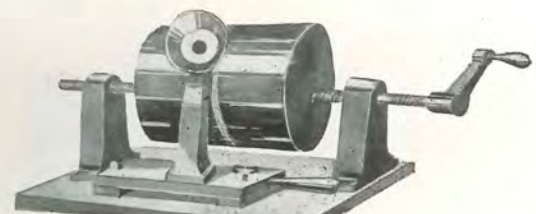


FIG. 52.—EDISON'S ORIGINAL MACHINE.

resisting stylus of the reproducing diaphragm when the latter was put into contact with the record and the record was revolved.

The greatest difficulty at this stage of the invention was to revolve the mandril or drum, upon which the foil was supported, with an even or regular motion. This became a matter of the first importance, inasmuch as the depressions, corresponding with the sonorous vibrations as to number in relation to time, would be registered unequally or out of their correct relation to each other. It became not less equally important, when revolving the mandril to reproduce the record, to do so with the same regularity, in order that these mechanically repeated vibrations might preserve that periodic value or rhythm which is of the essence of musical sounds. It is well known that musical sounds are technically differentiated from *noises* in that the former are produced by vibrations which are regular in their frequency, while

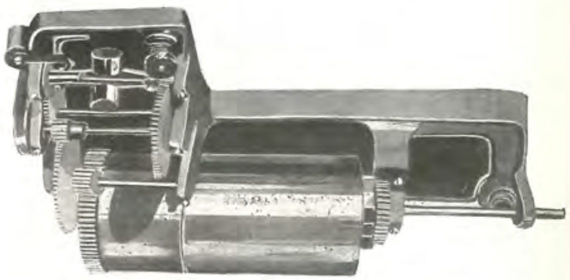


FIG. 53.—EDISON'S "TRIUMPH" MOTOR.

the latter are produced by those which are intermittent.

Many attempts were made to overcome this difficulty, the water motor and the electric motor being the first types constructed for this purpose. At length, the clock or spring motor, introduced by Mr. Greenhill, of London, fitted with a delicate governing apparatus, was introduced, being made by my old friend, Mr. Fitch (now deceased), and this was not only found to be quite satisfactory, but for all practical

purposes has never since been surpassed. Fig. 53 represents one of the best types of motors yet brought out for cylinder machines, and Fig. 54 represents one ot the earliest models of German disc motors, which was very popular for many years, but which has been improved upon considerably by Swiss manufacturers.

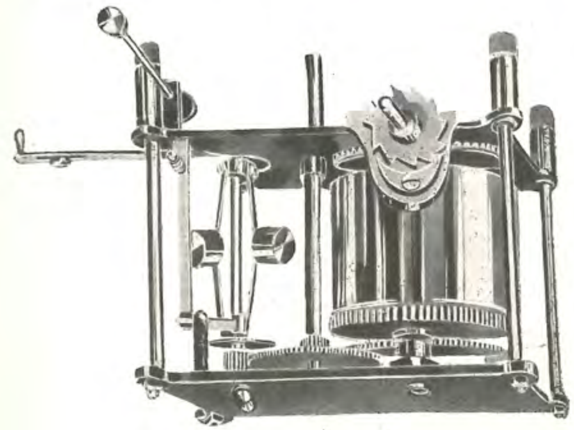


FIG. 54.—"EXCELSIOR" DISC MOTOR.

Both types of motor, although different in design, have one object—viz., the rotation of the cylinder or disc record at a given rate of speed.

The function of the train of wheels in these respective motors is to control the rapidity of motion and ensure steadiness in running. The number of teeth in the wheel and pinions are required to be worked out in relation to the actuating power residing in the mainspring or springs, and are more or less subsidiary thereto. There is no arbitrary connection, however, as considerable latitude in the variation of speed is permitted by the governors, which may be regulated by an adjusting device. To stop the motor when the spring is fully wound, it is only necessary to adjust the friction brake to its lowest point.

An important matter for motor manufacturers to consider is the dynamical relation of the actuating spring to the governors. There are many motors in the market to-day which are otherwise very well constructed, but whose governing mechanism is out of balance or proportion to the strength of the spring. The object of the governors is the regulation of the mainspring, and they must therefore be sufficiently delicate to respond freely and instantly to the least variation of pressure by the spring, and at the same time be sufficiently strong to check any spasmodic movement in the unfolding thereof. The governors, consequently, must neither be too heavy nor too light. Their size and construction must, of course, depend upon several minor considerations as well. The longer the train of wheels between the spring and the governors, the smaller and more delicate must the latter be.

In the communication of motion by the train of wheels there is loss of power at every point in the gearing, which is occasioned by friction.

Increasing a train of wheels is tantamount to decreasing the strength of the actuating spring, and *vice versa*, other things being equal. A very serviceable train of wheels for a cylinder machine motor is five, including the governor

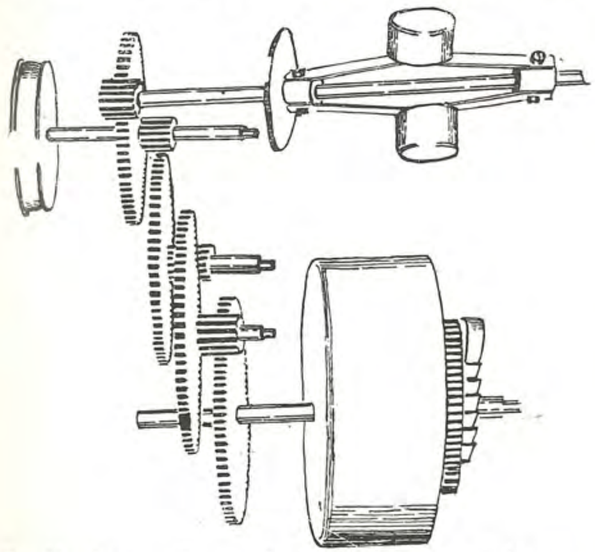


FIG. 51.—PLAN OF EDISON "STANDARD" PHONOGRAPH MOTOR.

shaft. The Edison "Standard" phonograph motor, illustrated in Fig. 51 shows the arrangement in plan, the first wheel (connected to the mainspring spindle) having 95 teeth, which engages with a pinion on the second shaft having 15 leaves. The wheel on the same shaft has also 95 teeth, and the pinion on the third shaft has 15 leaves. The wheel on this shaft has 88 teeth, which engage with a pinion on the fourth shaft having 13 leaves. The wheel on the same shaft has 124 teeth, and this wheel meshes with the governor shaft pinion, which has 17 leaves.

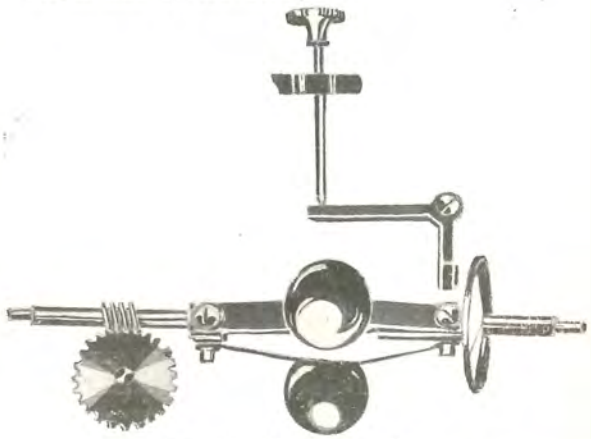


FIG. 52.—WORM-GEAR SHAFT.

It will be seen that a pulley is attached to the fourth shaft, the object of which is to operate the record mandril, which is furnished with a similar pulley, the motion being transferred by means of a belt.

A variation might be made in the governor shaft by the adoption of a helical screw—sometimes called a worm-gear—spindle engaging with a diagonally-cut wheel (preferably of fibre) on the pulley shaft. In that case the third gear should be eliminated. Greater

power is required to drive a train with this type of governing appliance, but the action is more steady, and back-lash is obviated. The pinion governing shaft must of necessity be mounted parallel with the other shafts in the train, as shown in Fig. 51, but the worm-gear arrangement must of equal necessity be mounted on supports giving it a rectangular position, as will be seen in Fig. 52.

On the reverse side of the spring drum or case it will be necessary to connect a toothed wheel which has engagement with a pinion or smaller wheel attached to the winding shaft. Mounted on the disc toothed wheel referred to, a ratchet wheel should also be firmly fixed, over which should trail a steel pawl to prevent recoil whilst winding up the spring. Its office is also to keep the spring at tension. A side view is shown in Fig. 53.

FIG. 53.—RATCHET AND PAWL.

The wheels of a motor are best cut from brass, and the pinions from steel. When the latter are made of brass they are not durable, and easily become distorted by the strain put upon them. Having a greater number of revolutions to make, they will wear down far more quickly than the wheels, and give rise to disagreeable noises when running, which should always be avoided as much as possible.

It will be obvious that the governing appliance is one of the most important parts of any motor, and requires very careful adjustment. It will be realised that, in the absence of the governor shaft, the mainspring, when wound up to its fullest extremity and suddenly released, would exert its power to unwind itself with great rapidity, and thereby set the last shaft in the train revolving with extraordinary velocity. The object of the governor is to check this rate of progression, as well as to regulate the motion conducted by the wheels. This check on motion is accomplished by the friction brake pad, which gently impinges against the friction disc. Two, three, or sometimes four balls or weights are employed, being attached to an equal number of flexible steel blades or springs, and in mounting these balls it is necessary that they shall be central, so that in their centrifugal swing they shall describe precisely the same circle. It is also equally necessary that they shall be of precisely equal weight, size and shape, in order that a correct balance shall be maintained and the air resistance made equal. The ends of the springs should be mounted on two metal bosses by small screws. The bosses should have sleeves to fit over the governor spindle. The shaft, pinion or helical, and one boss should be practically one, being relative

fixtures, but the other boss should be provided with an extra long and free sleeve to permit of its ready displacement under the influence of the expanding springs and balls whilst in motion. A lever or spring, to which is connected a brake-pad, should engage with the outer area of the friction disc, which governs its velocity; and the rate of speed may easily be made constant by means of a guide, the most convenient form of which is a threaded rod with a milled head, which can be easily manipulated to vary the speed as desired.

The operation of the governor is as follows: The pinion, on receiving its motion from the fourth wheel in the train, rotates the balls, because the springs which hold them are firmly fixed to the one fixed boss on the shaft. As motion is imparted to the pinion, the increased motion of the balls causes them to fly outwardly. This centrifugal tendency has the effect of drawing the other boss, which is one with the friction disc plate, towards the centre of the shaft, since it is quite free to slide in that direction only. In order to restrain this movement, the brake-pad is brought into play, and on pressing against the disc plate simply counteracts the centrifugal tendency to any desired extent by regulating the brake-pad. The brake-pad must be rigidly supported on the frame which carries the wheel train, and it is highly important that the friction disc plate shall be turned true and be set at a right-angle to the line of the shaft, otherwise the government of the motor will never be regular.

In mounting the governor shaft, it is highly desirable that it should be supported by steel centres or very accurate pivots, on account of the excessive speed which the shaft is required to make, so as to avoid side-shake or other foreign movement, which will seriously affect its capacity for doing good work. Indeed, more care should be bestowed upon the governor mechanism than any other part of the motor. It will be almost superfluous to point out that all the shafts in the train should be in perfect allignment with each other to ensure free and easy running.

The governing of the motor is important, because the mechanical motion of the record must necessarily be made with the same unerring regularity as that of the blank on the recording machine. A variation in rotation speed will only affect the pitch of the tones, but a variation in the motion or rotation itself will be fatal to the production or reproduction of any real tone. Given a certain number of vibrations per second, the diaphragm and stylus which communicate them to the blank must move, in order to permit of their uninterrupted registration—or, as a mechanic would say, for clearance. Vibrations are theoretically constant, and therefore, if the blank be moved slowly, the wave-markings will be closer to each other than if it be moved or rotated more rapidly. This question of

length of wave, determined by the motion of the registering medium, has more to do with the effect of tone than with the principle of motor governing, yet it is necessary to understand the periodic character of sound vibrations in order to more fully grasp the need for a recording and a reproducing machine to govern as perfectly as possible. It will be quite obvious from these observations that the cylinder or disc blank will register equal vibrations unequally, as related to each other, if the motion of the blank is not strictly regular. Vibrations which occur with perfect periodicity will be registered upon the blank without being equidistant, and the effect on their reproduction —however perfectly the reproducing machine may govern—will be to produce an entirely false tone. If the record itself be quite perfect in this connection and the reproducing machine does not govern properly, precisely the same result will occur. Manufacturers of records pay very great attention to the governing apparatus of recording machines, and spare no pains to get them as perfect as possible in this respect. It is equally important that reproducing machines shall be adjusted with the same accuracy in order to secure satisfactory results.

Reverting to the points of construction in cylinder machines, we will consider what is known as the " body," or upper portion, which contains the mandril and supports, together with the reproducing mechanism. The original scheme of moving the mandril and record laterally as well as rotating the same while the reproducer was mounted in a stationary position was soon discarded for the more practical or commercially economical method of moving the reproducer across the face of the record while in course of rotation. The same result was accomplished more easily by means of a sliding carrier, to which was affixed a half feed-nut, and which, in turn, engaged with a feed screw equal in length to the record surface. Whether this form was suggested by the general types of screw-cutting lathe, I know not, but all that is embodied in the one is contained in the other.

The original standard cylinder record thread or track was arbitrarily established by the early manufacturers as 100 to the inch—although some early Edison records were made with double that number of threads to the inch. I have before referred to the more recent Edison achievements in 200 thread recording, which are known as "Amberols." Being duplicated in celluloid, they have the advantage of durability as well as delicacy in tone, which their earlier wax prototypes did not possess. The Columbia Graphophone Company were first to market a cylinder machine to accommodate wax records, and the reproducer carriage was actuated by a feed-screw, geared with the mandril, to ensure a lateral motion to the reproducer corresponding to the track of the record. The thread of the feed screw being

cut as 50 to the inch, it was only necessary to gear the spindle at two to one from the mandril to ensure that each revolution of the

FIG. 54.—PHONOGRAPH FEED GEAR.

mandril would advance the reproducer carrier one-hundredth of an inch. See Fig. 54.

The Edison machines of the cheaper types were arranged in like manner in this respect, but a far better principle was employed by Mr. Edison in his "Home," "Triumph," and

FIG. 55.—EDISON "HOME" MACHINE BODY.

"Concert" types of machine, consisting in the feed screw and mandril being one. The thread, of course, was cut or otherwise made at 100 threads to the inch. Gearing was thereby dispensed with, the movement was more even, and all possible backlash was avoided. See Fig 55.

The disc machine, originally introduced by Emile Berliner, was operated in reproduction by a trailing device, by means of which the sound box (which corresponds to the reproducer of cylinder machines) was carried across the record with a swinging arm, freely pivoted. The more durable nature of the disc record composition enabled this to be done without great damage to the record, unlike the early cylinders, which were made of comparatively soft wax. A further modification of this trailing method was introduced some years ago, in what is now well known as a tone-arm, which enables the horn, by the use of a rigid bracket, to be supported rigidly without need of movement. It was found that, apart from the matter of greater convenience, the tone arm had a sensible effect upon the reproduced tone, which improved it as a whole by suppressing a great deal of the minor mechanical defects incidental to the methods of record production. The tone-arms were made of metal throughout, but I found by experiment that a greater improvement was effected by the employment of a closely grained wood tube between the sound box and the second elbow, especially if its interior was coated liberally with a solution of shellac. This innovation materially eliminated a metallic character from vocal reproductions, and gave a beauty to orchestral and string reproductions which were entirely

artificial in other circumstances. The metallic connections of the arm just supplied all that was necessary to preserve that amount of brilliance without which a really good reproduction is considered to be deficient. See Fig. 56.

FIG. 56.—SEYMOUR TONE-ARM (TYPE A.)

Although the general design of cylinder machines has remained much the same from the original models, there have been endless variations in the externals of the disc machines in late years, particularly since the introduction of what is known as the "hornless" or "cabinet" type. Every conceivable style of furniture effect has been exploited—as though people were ashamed to possess the real thing—to impart attractiveness to the instrument. It is true that these machines of the concealed horn variety have imparted a new character of tone to the gramophone, perhaps the most noticeable feature of which being the reduction of record surface noises by the arrangement of a lid to close down over the record and tone-arm. This feature certainly has its value, but the free, open tone of the horn type of instrument has been in a large measure sacrificed to the exigencies of the inverted tone-arm and amplifier, which latter is usually covered in and rigidly fixed at its largest extremity to the walls of the cabinet. The bad practice of this arrangement in construction is at once obvious in the reproduction of vocals, which invariably lowers the pitch of the voice and produces a boxed-up contortion of the human voice. In the case of stringed instruments, however, it must be confessed that this artificial reverberation adds ponderosity to the tones, which generally suffer from weakness in the recording. In both recognised types of machine—the horn and the inverted amplifier types—therefore, there are both advantages and disadvantages. What is desirable, in my opinion, is a new form of machine, constituting a mechanical synthesis of the two aforementioned types, and providing all the advantages of the one without the disadvantages of the other.

The " Superphone " is an instrument which I have designed and constructed on the lines suggested. It is a horn machine, properly speaking, but when the horn and resonating

tube are removed and put away when not in use, there is nothing about it to suggest the

Fig. 57.
The " Superphone."

gramophone, inasmuch as the usual appurtenances of the conventional instrument are completely concealed, as will be seen by a glance at Fig. 57. Instead of the cumbersome tone-arm bracket, an iron casement is fitted to the back of the cabinet, which covers in the tone-arm below the level of the lid (and is consequently out of sight), and to which the resonating tube and horn can be simply and instantly attached. The lid is hinged, and covers in the record, tone-arm, and sound box. I have made application for a patent in respect of this arrangement of gramophone and phonograph construction, and the simplicity of the idea is such that it is capable of an extensive variety of designs as far as the cabinet itself is concerned.

It would be out of place for me to enlarge here upon the merits of this combination, but I may say that the results have fully realised my expectations. It at once presents the free and open tone of the horn machine without the usual raspiness and blatancy which invariably characterise horn machines. It diminishes surface noises to the minimum without diminishing in the least any volume in the record: the inverted horn machines reduce both correspondingly. Moreover, I have noticed a considerable increase in its carrying power, that is to say, in its capacity to be heard at a greater distance without the character of tone being changed, and I attribute this to the separating process with regard to the surface noises. In the usual construction of horn machine, there are, obviously, two

sources of origin with regard to surface noise: one being that caused by the contact and friction of the stylus with the hard record surface, carried to the reproducing diaphragm, and necessarily transmitted through the horn; the other, that caused by the same thing and setting the free air in disturbance outside the horn. By suppressing this second source of foreign noise, as is effectually done by a simple covering lid, there is a remarkable increase in the purity as well as in the volume of tone emerging through the horn, which is due to the removal of acoustic discordance to this extent. To be sure, this advantage has been achieved in some measure by the inverted horn machines, but not nearly to the same extent, from which I conclude that the inverted tone-arm and horn arrangement is bad in principle. I have made very careful comparisons in result with the two types of instrument, using the same sound box with each, as well as amplifying device of the same configuration, size, and material. By also using the same record and same room (for different rooms have altogether dissimilar acoustical properties), I did everything possible to equal the conditions, but the inverted horn machine was a very poor second in the match.

Now, according to the generally recognised authorities on acoustics, sonorous vibrations are propagated in all directions from their point of origin. If this were so, the machine with the inverted horn would not be inferior to that with the ascending horn. How is this discrepancy between theory and fact to be explained?

The horn machine illustrated in Fig 58 is one of the popular models of the Gramophone

FIG. 58.—A GRAMOPHONE CO. MODEL.

Co., and serves to show the generally recognised principle of design adopted in horn machine construction. There are many minor variations, of course, in the accessory equipment of horn machines. The special feature of the Gramophone Co.'s machines is the

swan-necked tone-arm, which enables the sound box to be easily turned upside down to facilitate the change of needles as required. In addition to this utility, it has the effect of analysing composite sounds and of reducing objectionable harshness in some records, so that it may be called a resonating device in one form. Obviously, other means would accomplish a like effect, but improvements in

FIG. 59.—EXHIBITION SOUND-BOX.

the mechanical production of records would render all such devices superfluous.

The "Exhibition" sound box, which is also part of the equipment of the Gramophone Co.'s instruments, has some very good points, notably its capacity for "attack," due to cross stylus tension springs and comparatively small diaphragm, but this is an advantage in one direction which is offset by a disadvantage in another—the failure to produce breadth of tone. On the other hand, sound boxes fitted with excessively large diaphragms are able to deliver a corresponding

FIG. 60.—A COLUMBIA "GRAFONOLA."

fulness of tone at the expense of clean definition.

The subject of sound boxes and reproducers will be dealt with in a special chapter,

being one that calls for more than casual treatment, for upon the merit of this indispensable accessory depends nine-tenths of what goes to make up a really good reproduction of any record.

All the leading manufacturers vie with each

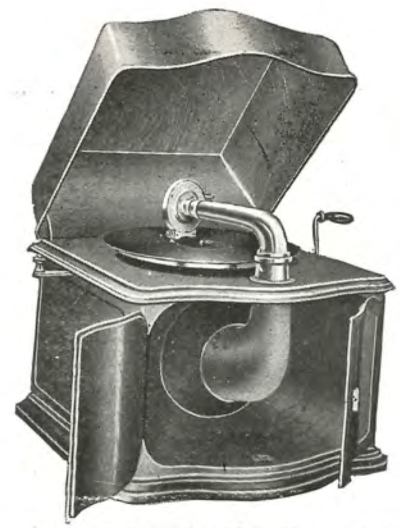


FIG. 61.—PATHE'S "NEW COLONIAL."

other in producing cabinet instruments in the most elegant designs. The Columbia Grafonola, No. 27, fitted with adjustable shutters for varying the reflection of sound, and a cupboard beneath for the storage of records, is a product of considerable taste. (See Fig. 60.)

Messrs. Pathè Fréres have introduced a somewhat unique type of instrument, known as the "New Colonial," with a novel means of throwing the sound waves through an inverted tone-arm against a parabolic reflector which reverses their direction. This model has the advantage of portability and compactness, and

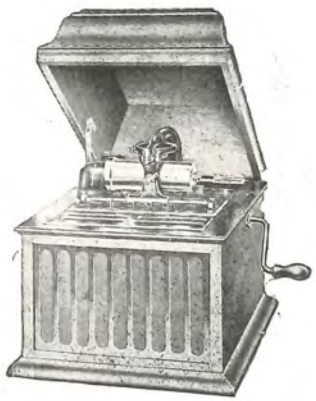


FIG. 62.—AN EDISON "AMBEROLA."

being made of metal throughout, is brighter in reproduction than most other instruments of the inverted horn variety. (See Fig. 61.)

The Edison Co.'s instruments are now exclusively made with inverted tone-arms and amplifying horns, the horn types having been abandoned to meet the demand for this upside-down state of affairs. This applies both to the

cylinder and disc machines. A cylinder "Amberola" is shown in Fig. 62. A decided advantage in construction, however, lies in the suspended internal horn, which effects, to a considerable extent, the removal of muffled tone so characteristic of inverted horn machines.

CHAPTER XVIII.

REPRODUCERS, SOUND BOXES, DIAPHRAGMS.

The subject of reproducing apparatus, which includes the reproducer or sound box, as well as the amplifying horn, next merits attention, and so varied and extensive is the range in character and materials employed in the construction of these that only those will be considered at length which have been found by experience to be really successful. The cylinder-machine reproducer was the original type of transmitter, and, with the necessary variation in the means to agitate the diaphragm, the latest types of disc-machine sound box are constructed upon the same leading principles.

The diaphragm is, of course, the most important factor in a reproducing appliance. The "shell" or casing, in which the diaphragm is fitted, may be made of almost any hard substance, but metal is almost invariably used because of its greater convenience in attaching the minor fitments, as well as adding brilliance to the sound, when compared with the less dense materials, such as vulcanite, fibre or wood. The shell is merely a very shallow box with an outlet in the centre, usually made circular, of which the diaphragm, rigidly supported in an annular recess between two rubber rings or washers, called gaskets, constitutes the

lid, so to speak. A connecting stylus must be connected to the centre of the diaphragm, in order that the undulations or sinuosities of the record in motion may affect and vary the movements of the stylus which transmits them to the diaphragm as variable thrusts. It will naturally follow from this that the larger the amplitude of the sonorous waves in the record, the greater will be the thrust, and hence the greater the volume of sound emitted in the reproduction.

The Edison reproducers are constructed with a lever, one arm of which is provided with the stylus to engage with the record, the other being connected by means of a link to the diaphragm centre.

A glance at Fig. 63 will show the general construction of the latest Edison reproducer in side elevation partly in section, and a bottom plan view thereof. The reproducer comprises an annular member 1 with an extension 1^1 and an upper conical member 2 provided with a neck 2^1, the periphery of member 2 being secured between two rings 3 and 4, threaded into the interior of the annulus 1. The diaphragm 5 is placed between rubber gaskets 6 and 7, which are held securely between the ring 4 and a third ring 8 threaded into the bottom of the member 1. The stylus 9 is mounted in a lever 10 rotatably supported on a pivot 11 which is mounted at its ends in spaced bearings 12 projecting downwardly from the lower surface of the weight 13. The floating weight is connected to the outer end of the extension 1^1 by a spring 14 or other suitable resilient member, and swivelling means are provided in screws 17 securing a pivoted member 18 loosely fitted in a vertical opening in the outer end of the arm 1. The numeral 19 repre-

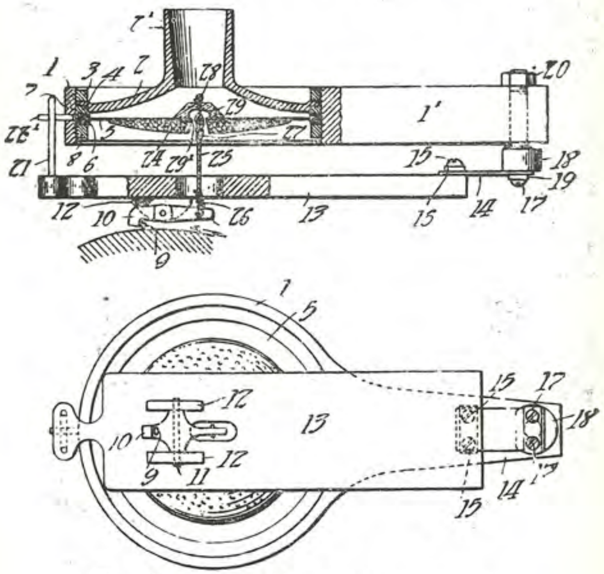


FIG. 63.—EDISON MODEL B REPRODUCER.

sents washers inserted between the screws 17 and the head of the member 18, and the numeral 20 a nut for securing the pivot member 18 in place. The swivelling or pivoting of the floating weight enables the stylus to closely

track the centre of the record groove, which is very important for eliminating foreign noises due to side-shake. Secured to the front of the floating weight is a loop 21 having an upper portion 22 in the shape of an inverted V, this latter portion being adapted to be engaged by a pin 22^1 secured to the front of the member 1 to centre and support the floating weight when the reproducer is raised by the carrier arm after operation.

An important feature of this reproducer, which is certainly one of the finest yet brought out for use with indestructible records, is its somewhat novel diaphragm, being composed of thin sheets of Japanese paper shellac-glazed, with a smaller disc of cork affixed to its centre on the under side. In place of the older metal link connecting the stylus lever to the diaphragm adopted by Mr. Edison in his earlier phonograph reproducers, a link of cotton is employed which effectually removes any metallic character from the reproduction, and improves tone correspondingly, leaving the diaphragm alone free to translate any metallic quality of tone which may be of the essence of the record, and not something *ab extra*. It is claimed that by the adoption of a relatively thick centrepiece of cork, as referred to, that the diaphragm is not subject to strains which permit local buckling when vibrations of large amplitude are emitted. I have found, however, that a diaphragm composed wholly of comparatively thick cork possesses the same property of smoothly reproducing vibrations of large amplitude, with wonderful clarity, when used with a stylus mounted in a dome in the floating type of cylinder reproducer. As a means to obviate diaphragm buckling, it is difficult to imagine a more satisfactory mechanical arrangement than that which is embodied in the construction of the Edison reproducer as a whole, but I am not quite sure that it is really desirable to take measures for the prevention of this alleged extraneous movement. Indeed, I am inclined to believe that all reproducers and sound boxes of the simple types largely depend for their efficiency upon this very principle of buckling the diaphragm. In fact, the ordinary disc sound box diaphragm, which is actuated by a stylus bar whose fulcrum is a fixed point outside and independent thereof, must necessarily be buckled in a continuous manner when in operation, inasmuch as the stylus bar, having a lever motion, can only describe an arc in its backward and forward working, and therefore must strain and buckle the diaphragm accordingly.

As long as a material for the diaphragm is sufficiently elastic to recover, in other words, possesses the ability to resume its normal plane form after each vibratory thrust, that is all that is necessary to ensure a good reproduction as far as the diaphragm element is concerned.

It is quite certain that the mere motion of a diaphragm, to and fro, or inwardly and outwardly, produces no sound audible to the

human ear, and that the essential thing is to communicate *shocks* to the diaphragm by mechanical means, of which the diaphragm motions referred to are merely the incidental effects. Now, since the track of a record (acting as a *cam* to sway the stylus in opposite directions, corresponding to the double motion of sound waves, in their varying amplitude and frequency) does this with considerable smoothness, it follows that the shock or thrust is due to other causes than the mere contact of the stylus with the record. Doubtless the extreme rapidity of motion in opposite directions is responsible for much molecular disturbance in the communicating substances employed, but by far the greatest change is effected in the molecular displacement of the diaphragm substance, which, being encased in a resonating chamber, or shell, is powerfully augmented for the production of sound. It is this fact which renders some materials better than others for diaphragm use. A very thin indiarubber diaphragm, mounted in a reproducer or sound box shell, would move inwardly and outwardly just as perfectly as any other by the action of the stylus, but very little sound would be generated by a diaphragm of this character. The best diaphragms, consequently, are those made of hard, elastic substances. Glass was originally employed for this purpose almost exclusively, both for recording and reproducing, and nothing has yet surpassed it for brilliance and effective elasticity. Its extreme fragility, however, has put it out of use for reproducing purposes, talc or mica having largely taken its place. In some respects this latter-named substance has superseded glass, owing to its more sluggish movement and consequent broader tone which it emits. Further, it is less liable

FIG. 64.—SEYMOUR CYLINDER REPRODUCER. (CARBON DIAPHRAGM.)

to damage by careless handling, and is more "commercial." Being laminal in structure, however, it is liable to split at the least provocation, and is therefore less constant in its effects than glass. I have not heard that anyone has experimented with the production of

glass compositions containing metallic ingredients, but I am convinced that an excellent field of research lies in the direction of malleable glass for diaphragm use. In the early nineties I introduced baked carbon sheet for the purpose, with remarkable results as to strength and fidelity of tone, but a certain deficiency in brilliancy was noticeable. Its greatest success was most conspicuous with records of large amplitude.

Sound boxes for disc machines vary considerably in the manner of mounting and tensioning the stylus bar but the fundamental principles of all are the same. The "Exhibition" sound box (see Fig.59) is shown with a stylus arm mounted on a bridge which rocks on two knife-edged studs, being governed by two powerful cross springs to prevent excessive vibration. This method is probably the best form of check action to prevent over-vibration and to promote rapidity in recovery of the diaphragm, but its disadvantage is the shrill character of the tone moulded by this arrangement, and the degree of record surface noises developed by this very principle. Moreover, all sound boxes constructed with such severe check springs have necessarily to be very heavy in weight to provide sufficient inertia in the sound box mass to allow the diaphragm, and not the box as a whole, to move in relation to the record markings. I have found that greater volume and better tone can be secured by a modification of such cross springs, in being free at one end.

The employment of a novel substance, which I have called "Hornite," is very successful in the combination by enlarging tone while diminishing the surface noises of records. (See Fig. 65.)

In mounting a sound box diaphragm, it is

FIG. 65.—SEYMOUR (MODEL A) SOUND BOX.

very desirable, that when at rest, it should be quite flat, and not be tensioned unequally so as to give it either a concave or a convex character, for the obvious reason that in either of these circumstances the full capacity of the diaphragm will be restricted by the strain exerted upon one side as against the other. The

cushions of rubber, between two of which it is placed as rings at the edge, should be more or less flexible or resilient, as it has been found that a pliable seating of this character not only answers admirably as a support for the diaphragm, but acts as an excellent damping means without, at the same time, having a reducing effect. The contact of a rubber cushion with the diaphragm at any other point nearer its centre, or more active area, would cause a considerable reduction of tone, corresponding in degree to its position and to its contiguous pressure. It should also be particularly borne in mind when fixing and adjusting the stylus bar upon its rockers or fulcrum, that it should be rigid, having the ability only to rock to and fro for the purpose of pushing the diaphragm inwardly and pulling it outwardly without the least side-shake or other extraneous motion. A very small screw is generally utilised to tightly connect the end of the stylus-bar to the centre of the diaphragm. It is imperative that the contact shall be quite firm or there will be a great loss of power in vibrating the diaphragm and a corresponding inferiority in the quality as well as in the quantity of sound reproduced. It appears to be a matter of small importance what material is employed to form the ring or frame of the sound box, but a great deal depends upon the sonorous quality of the substance which is employed as a back-plate, and it is remarkable what a variety of tonal effects is capable of being produced by variations in materials, and by variations in thickness. A thin back-plate will invariably produce what is known as "thin," or shallow, tone, and with each thickening up will ensue a corresponding solidity of tone, to a certain point. There is doubtless a critical limit to be observed, for if it is carried too far in any material sonorous absorption will take place and a peculiar obscurity of tone will be apparent. I have found that one-eighth of an inch is the best average thickness for the purpose, either in metals such as brass, white metal alloys, or in the fibrous substances. The latter are very absorptive, by the way, as compared with the former. They yield a richer and more mellow tone on the lower registers, but lack brilliancy. On the whole, I have found that certain alloys of aluminium, such as "Fortalium" and "Magnalium," are superior to brass (the material most commonly used) for this purpose, whereas ordinary aluminium is extremely "thin," but at the same time is very clear or definitive.

From the foregoing observations it will be reasonable to assume that the sound box plays as important a part in moulding the character of reproduced tone as the record itself. The record *per se* is inert—it does not contain within itself the sound as such, but merely carries upon its surface the vibratory marking somewhat coincident with the motions of the atmospheric waves which produce sound. I say "somewhat coincident" because by the very restrictions and limitations of the recording stylus motion, these

waves are never wholly or accurately registered by the prevailing means employed. At present, we are able to utilise line motions only, whereas, the waves of sound are propagated in every direction. Much may be and is accomplished in practice by concentrating appliances in the making of records to supply added robustness or volume to sounds which would otherwise be weak, not because these sounds are intrinsically weak, but because of their greater complexity of wave motion. The simple, percussive sounds yield by far the most realistic result in record reproduction, and that is because such sounds are produced by wave motions of a simpler order, to which the simple lever actions of the recording and reproducer styli are more nearly able to correspond.

The modifications and variations in reproducing means are somewhat extensive. The cult of the "fibre" stylus, as a variant of the steel needle for disc sound boxes, has slowly but surely developed in recent times, its devotees being mainly those who are averse to excessive volume at the expense of pure tone with regard to the reproduction, and the employment of a stylus of this character is certainly advantageous from the point of view of economy, inasmuch as records played by such means are virtually indestructible. The idea was originated by Mr. Frederick Durize Hall, of Chicago, and patents were granted in 1908 (British specification numbered 24,932, of 1907). The novelty of the invention may be summarised in the following claims set forth in the complete specification: "1. A reproducing needle for talking or sound-reproducing machines, consisting of a material of less degree of hardness than said disc, and of angular cross section.

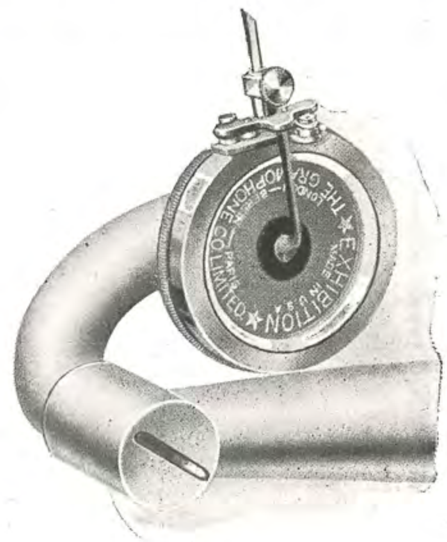


FIG. 66.

2. A reproducing needle for talking or sound-reproducing machines of a vegetable fibre material, preferably bamboo, having its end or ends cut at an angle to form the operative point or edge of the needle. 3. A reproducing needle for talking or sound-reproducing machines as

claimed in Claim 2, having an angular cross-section, the operative portions of which are the edge or edges formed by the meeting of the sides and ends thereof. 4. A reproducing needle for talking or sound-reproducing machines, as set forth in Claim 2, in which the outer edge is of harder material than the remaining por-

FIG. 67.

tion. 5. A reproducing needle for talking or sound-reproducing machines consisting of layers of vegetable fibrous material secured together and cut to a point or edge. 6. A reproducing needle for talking or sound-reproducing machines, substantially as described or as illustrated in Figs. 4 and 5 or in Figs. 6 to 8 of the accompanying drawings."

In order to use the bamboo stylus, which is made triangular in cross-section and pointed, it is necessary to have recourse to the cutting of a triangular hole in the socket of the stylus-bar of the sound box, and a glance at Fig. 66 will show the fibre stylus in position. It is necessary to repoint the stylus after each reproduction, and handy little appliances are on the market to do this accurately and instantaneously. The "Wade" cutter, an American importation, is a popular type, fashioned like a pair of hand pliers, with a triangularly grooved guide and a blade set at the correct angle to ensure a clean point by its operation. This is sold for a few shillings, and some such device is almost indispensable to the constant user of the fibre stylus. For those who are averse to having their sound box stylus sockets cut to accommodate the fibre, a neat little accessory has been marketed, having a short needle shank projecting from its upper part to insert into the ordinary socket needle groove, and having an open triangular groove in its body for insertion of the fibre, which can be adjusted as to the degree of projection therefrom. (See Fig. 67.) If an ordinary stylus socket has been cut, as before mentioned, to allow of the insertion of the fibre needle, it generally loses a great deal of its effective value for the use of the steel needle, inasmuch as the latter is so much thinner or smaller in radius; and, however rigidly it may be clamped by the little set screw, it has a tendency to "shake," instead of

being firm, which results in an appreciable loss of tone. It is always desirable to maintain as great a rigidity as possible in the stylus, to ensure the best effects in reproduction, and an ingenious little attachment brought out by Mr. Daws Clarke, of Manchester, known as the

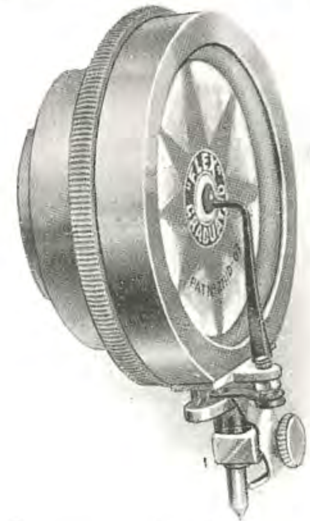


FIG. 68.

Needle Tension Attachment, by means of which either a steel or a fibre needle is rendered more rigid in this particular than ordinarily, effects a great improvement in tone, particularly when used in conjunction with fibres. (See Fig. 68) which shows how the attachment is connected to the stylus-bar, the entire pressure of the set screw being exerted, through the steel arm below it, in close proximity to the stylus point.) By removing any flexibility which may reside in the stylus outside the socket, the volume of sound is increased and the tone is rendered more firm and definite, for the obvious reason that a smaller dissipation of mechanical energy takes place between the stylus point and the reproducing diaphragm.

It will be understood that while fair average volume may be secured from the disc through the medium of the fibre needle, it is not to be compared with the ordinary steel needle for tonal strength. The source of all reproduced sound in connection with cut records and simple reproducers is the friction resulting from the stylus point and the material or substance of the record itself. The old wax cylinders were comparatively soft in tone for the reason that their material was comparatively soft, even though they were reproduced with a stylus as dense as sapphire or diamond. In the employment of fibres in connection with the records, the substance of which is exceedingly hard in comparison with wax, we reverse the process, in a sort of way, and reach a similar result. For fibre needle reproduction, therefore, it appears to be desirable to shorten the lower arm of the stylus lever as much as possible, in order to render the stylus section as rigid as possible, as well as to increase the thrust to the diaphragm by the amplified leverage. To this end I brought out a sound box some years ago

with a stylus bar designed to accommodate the fibre needle and to render it adjustable, so that the point alone could be made to project from

Fig. 69.

the socket. (See Fig. 69.) I also registered another form which enables the fibre needle to slide behind the upper section of the stylus bar, thereby bringing the stylus point nearer in line with the fulcrum pivots, which is certainly desirable. In a third form I mount the fulcrum pivots upon the face of the annular ring of the sound box, and by this means secure that the fibre is in line with the fulcrum and substantially in line with the upper arm of the stylus as well. This form has shown a marked improvement in result, and a fourth form, upon which I am experimenting on different lines, promises still greater improvement. Notwithstanding this, I am far from convinced that the fibre needle method of reproducing records will lead to any sort of finality in methods. For it has been repeatedly noticed that only certain classes of records reproduce with any satisfaction by means of fibres. Stringed instruments and reeds, as well as vocals, especially those of the lower registers, are reproduced with their natural *timbre*, but brass bands are seldom successful. Moreover, the relatively successful use of fibre needles requires some degree of skilful manipulation, as the points sometimes go down before a reproduction is through, on account of a bad piece of the cane happening to occur at the point. The records with the most open track are generally the best for fibres, and used in connection with phono-cut records of the Pathé type, they appear at their best, and give wonderful results in volume with this class of record as well as considerably minimise the harsh surface noises which are characteristic of phono-cut records pressed in the hard shellac compositions.

CHAPTER XIX.

Sound-Magnifying Devices.

The microphone is usually but improperly identified with Professor Hughes' discovery of the production of acoustic intensity by interposing variations of resistance in a voltaic circuit. The principle, or rather its application, does not magnify sound in the proper sense of the word, but changes the strength of the current from the proximate source of sound, as, for example, a telephonic diaphragm.

Microphones cover a far wider field than the electrical, as a matter of fact. But the application of the electrical microphone to the phonograph or gramophone has never proved a success, and the difficulties seem to be insurmountable. There have been many attempts to accomplish something satisfactory in this connection, but they have been mostly negative. The microphone, as far as my own experiments have gone, appears to work fairly well with certain orders of sound and not with others. It will augment the small sounds in a remarkable manner, but the same constructed apparatus completely fails to augment the larger sounds in the same relative degree. The foreign noises, also, due to internal causes which are not easy to overcome, are very much greater than those engendered by the friction of needle and record in ordinary reproduction. Compressed air appliances of the syren type, such as have been constructed by Short, Parsons and others, offer far greater possibilities of success. Short seems to have been the first to employ a jet of air under pressure for the reproduction of sound records, the air being allowed to escape by means of a minute valve, operated by a lever to which a stylus was attached, the undulations of the record serving to operate the lever and to regulate the valve accordingly. When his machine was demonstrated before the Edison-Bell Company many years ago, it caused no little astonishment, its volume capacity being so great as to be heard a mile distant.

In his British Specification (No. 22,768 of 1898) he describes his invention as relating especially to articulate utterance or other sounds "produced by the vibration of diaphragms in telephones, telephonic instruments, or the like, or produced by mechanical means by phonographic instruments, and it has for its objects methods of increasing the volume and audibility of such sounds, so that they can be made audible at long distances." The method, he continues, "consists substantially in the use of devices more or less equivalent to the 'relays' ordinarily used in the transmission of telegrahic messages to long distances; for which purpose I cause the vibrating diaphragm of a telephone receiver, or of the stile or pointer which presses upon the cylinder of a phonograph, to cause corresponding vibrations or undulations in a column of air, steam, or other suitable gas or vapour, these vibrations or undulations being produced, upon a largely magnified scale, by the governing vibrations of the telephone disc, or the phonographic point, and being directed in any required direction if desired by means of a trumpet-shaped apparatus through which they are delivered.

"The apparatus itself, which is influenced and operated by the vibrating telephonic disc, or by the stile or pointed instrument actuated by the permanent depression produced by sound in the usual way upon a phonographic cylinder or disc, resembles somewhat in principle the apparatus known as the 'Syren,' in which a column of air or steam passing through a tube or chamber is cut off more or less completely, and renewed, in very rapid succession, so as to cause in it correspondingly rapid vibration or undulations which themselves result in sounds of any desired magnitude and power, according to the size and character of the apparatus; the pitch of the sounds produced being dependent upon the number of interruptions or undulations per second, so that by causing such number of vibrations to be determined by the vibration of the disc of the telephone or the stylus or point of the phonograph, the sounds produced become largely magnified reproductions of the sounds given off by the telephone or phonograph."

It will be understood that the ordinary simple phonograph reproducer or sound box, like the telephonic diaphragm, depends wholly for the ability to utter sounds upon the principle of air undulation, and the only real departure from the principle involved in the apparatus devised by Short is that the air so acted upon is under compression. The pressure on the air enclosed in the ordinary reproducer "shell" is small in comparison to that exerted by a super-induced pressure current acting in free air. If carbonic acid gas were substituted for ordinary atmospheric air in the chamber of an ordinary reproducer, the volume would be greater by the relatively greater friction of the gas, which is more dense, of course, than air. The phenomenon of sound, therefore, is seen to depend on friction, pure and simple.

Short favoured the method of vibrating a diaphragm by means of the air jet, but later experiments proved that better results were obtained without the use of a diaphragm at all. Parsons worked on these lines, and the "Auxetophone" was a practical development of the idea. He permitted the air under pressure to operate in the free air confined in the usual amplifying horn. It may be useful to set forth his own claims from the British Specification, No. 10,468 of 1903, in which he states that "the air-operated reproducer is very much more efficient, and that losses between the energy imparted by the record to the reproducing stile and sound energy produced are far less than is the case when the energy of the stile is impressed directly on the air through the medium

of a diaphragm, and also that the original sound wave is more correctly reproduced."

In developing his apparatus, Parsons found that the following leading principles must be observed. As a measure of the forces of momentum in the moving parts of a reproducer, and as a basis of calculation, the force of acceleration at the point of a reproducing stile when loud music is being played often amounts

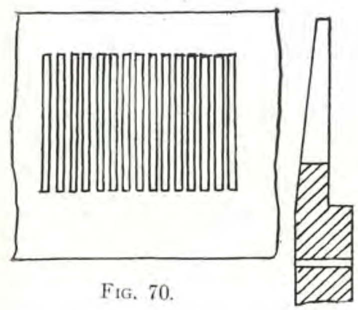


Fig. 70.

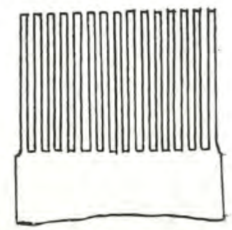


Fig. 71.

to one hundred times gravity, the amplitude of the vibrations in this case being something like 0.003 inches and the periodicity about 500 per second.

The energy required to vibrate a small valve at a given number of periods per second varies as the square of the amplitude of vibration and also as the square of the frequency. It varies, also, as the integral of the mass multiplied by the square of the amplitude of oscillation or radius about the line of oscillation.

From these considerations it became of first importance to restrict the amplitude of the valve movement to the smallest possible proportions. To this end Parsons constructed a special form of grid valve (see Figs. 70 and 71),

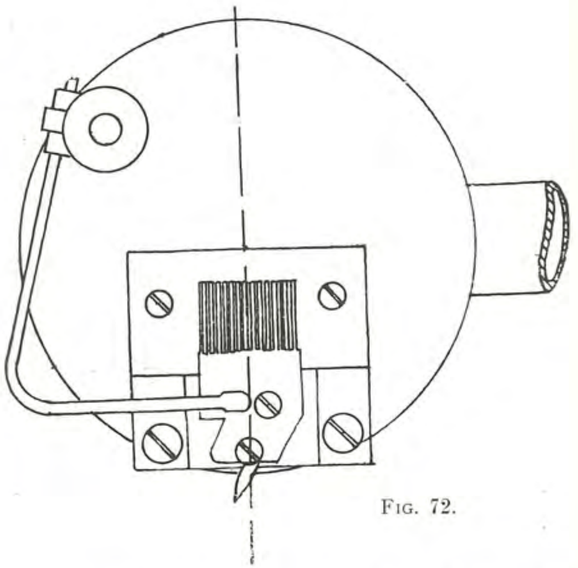


FIG. 72.

working like a flute key, pivotly, and being held to the necessary tension (in order to counterpoise the normal air pressure) by a spring capable of adjustment. The construction of the apparatus is shown in Figs. 72 and 73.

The compressed air is supplied, of course, by

a subsidiary small rotary pump capable of delivering a continuous pressure of several pounds to the inch, three or four being usually sufficient. In order that the pressure may be both uniform and constant, it is best to be first delivered into a container, thence conveyed to the reproducer proper. The air should be filtered through cotton wool before it is transferred to the reproducer valve to prevent its being clogged by small particles of dust.

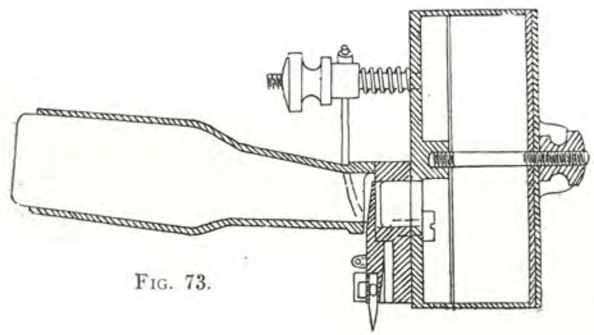


FIG. 73.

The intensity of sound produced by a reproducing device of this character is very great, and is very true to correct tone, unlike the ordinary reproduction by means of a diaphragm, which, in most cases, imparts supertones, originating in the diaphragm itself. It is suited only to record reproductions in public halls or in the open air, for the reason that the volume of sound delivered, even with the use of a small trumpet or horn, is too overpowering to be borne for any length of time at close quarters, and, in addition, there results a rather powerful hiss (far more pronounced than that usually associated with the steel needle in ordinary disc reproductions). It will be supposed that the magnification of sound in

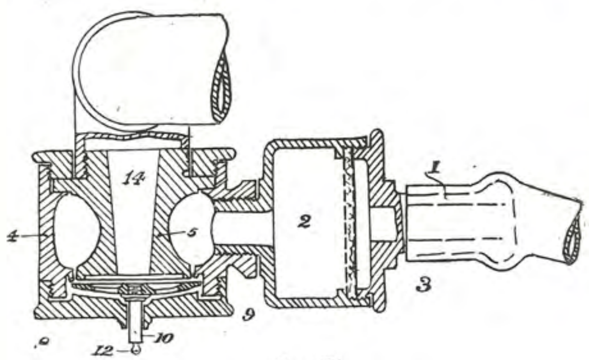


Fig. 74.

general will naturally increase the usual surface noises of the record to a corresponding extent, but this is not the case in connection with air-pressure reproducers. It is true the hiss is there, and to a considerable extent, but it is not at all due to the contact of the stylus with the record, but is due rather to the air under pressure escaping through the valve, the latter never being completely closed by the action of the stylus, but being in constant undulation.

A modification of the above apparatus was patented in 1906 by "The Compagnie Générale de Phonographes," etc., of Paris. The inventor claims that excellent results may be obtained by means of a simple seat valve, but the type appears to be applicable only to phono-cut discs, as Parson's "Auxetophone" is applicable only to the needle-cut variety. I was present at the Royal Albert Hall some years ago when Messrs. Pathé Frères gave a special demonstration of the "Orphone," which is the name by which the French air-reproducer

Fig. 75.

is known. The reproduction on this occasion of Pathé selected discs certainly was distinctly audible in every part of that huge building.

Instead of a spring to obtain tension for counterpoising the internal air pressure, the apparatus depends upon its own dead weight and the power of gravity to accomplish this object; but the valve action, in my opinion, is less perfect than that of Parsons', as all piston types, however carefully fitted, must be. Fig. 74 represents the form of its construction and method of operation, and Fig. 75 shows a plan view of the valve. In its working the compressed air passes through a flexible tube to the monthpiece (1) into a chamber (2), divided by a filter of cotton held by two perforated discs of metal or wiregauze. The air passes on to the box (4), in which is a core (5), and its only point of exit is at (9), which is a small annular space provided for that purpose. When the record is rotating, the weight of the reproducer causes it to follow a relatively level course, only the lighter valve, which is made of aluminium, being able to rapidly follow the undulations of the record. The effect of the latter is to open and close the annular opening at (9) in corresponding periods, and the compressed air escapes in puffs into the orifice (14) which leads directly to the amplifying horn.

We have now to consider an altogether different type of sound-magnifier, which does not depend on air under pressure for its effects, but which involves a purely mechanical principle. The original patent for this peculiar device was taken out by Daniel Higham in 1901, and consisted in the application of a friction reel and shoe, which reminds one of the chalk reel of Edison in the early days. The friction reel was interposed on suitable supports between the diaphragm and stylus lever, the shoe or band partly encircling it, one end of the band being connected to the diaphragm, the other to the free arm of the stylus lever. The reel was given a revolving motion, which caused the

band or shoe to grip it, thereby straining the diaphragm outwardly and giving it an extraordinary tension. In operation the undulations of the record worked the stylus lever upwardly and downwardly, which, in the former case, held the diaphragm tension firmly, and in the latter effected its release, causing it to return to its normal position of rest with considerable force in periods varying in frequency as the undulations of the record, and thereby generating a greater volume of sound in the reproducer than would otherwise be the case.

The principle was probably first conceived in connection with sound-reproducing appliances by Mr. Cooper, who applied it in the late seventies or early eighties in the production of records in solid brass, soon after Edison introduced the tinfoil machine, which latter has been on exhibit for many years at the South Kensington Museum. With the Edison machine, the vibrations of the voice were indented on a strip of tin-foil by a needle, or stylus, attached to the back of a diaphragm set into vibration by the voice. The effect was comparatively feeble, as only soft, yielding materials could be used, but Mr. Cooper communicated to the Franklin Institute particulars of a mechanical device, which he termed a "phonodynamograph," whereby the force might be increased which caused the stylus to press upon the metal sheet. The device was illustrated in *Cassell's Family Magazine* (1882), and is reproduced in Fig. 76, consisting of a pulley, A, which is surrounded by a cord, B, having one end attached to the centre of the vibrating diaphragm, C, and the other end attached to one end of a pivotted lever, D, which is shaped like a stylus, and disposed so as to indent a sheet of metal passing under it when the cord is pulled upon. Now, when the plate,

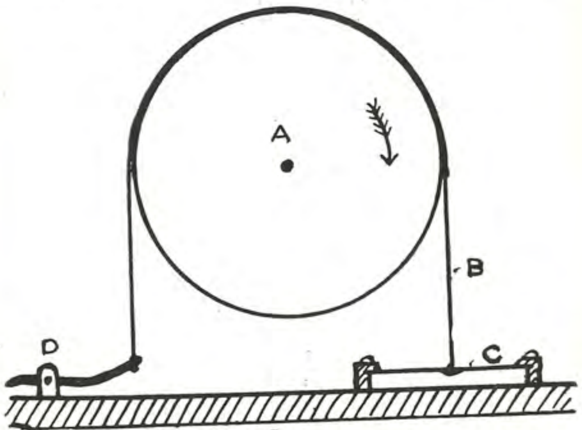


FIG. 76.

C, vibrates up and down, the cord pulls the lever, D, with a tension equal to the force with which the diaphragm vibrates less the friction of the cord on the edge of the pulley. But if the pulley, A, is rapidly rotated in the direction of the arrow, the lever, D, is pulled upon by a force equal to the vibration of the diaphragm plus the friction of the cord and

pulley. This friction increases with the speed of the pulley and hence the feeble vibrations of the diaphragm can be made to indent with considerable thrusting power. Little or nothing

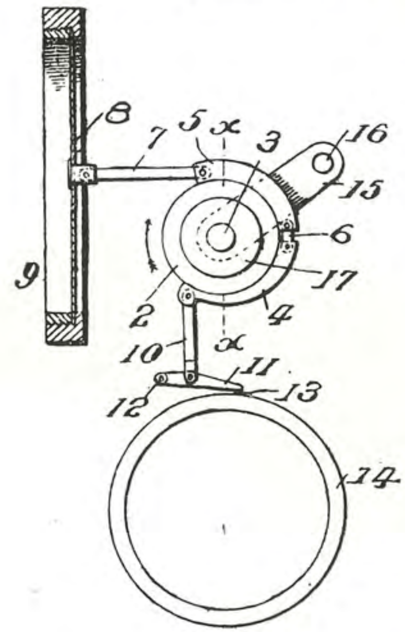


FIG. 77.

appears to have been done in this direction. But Higham appears to have been the first to work the principle out as a reproducing mechanism.

At a later period the Columbia Graphophone

Co. procured two patents for improvements, and put two models of cylinder machines upon the market with the improved appliances attached. In the British specification, No. 905, of 1905, by the High-am-o-phone Co., of New

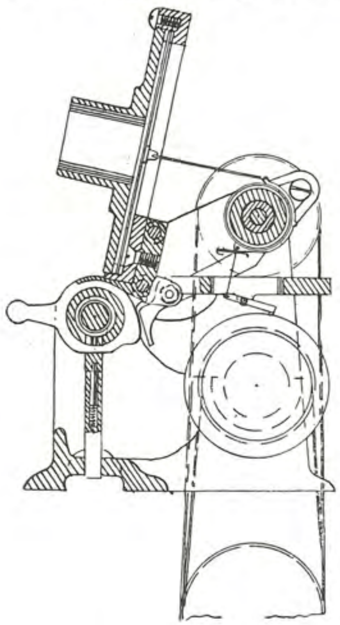


FIG. 78.

Jersey, a representation of the scheme is shown, which is reproduced in Fig. 77. The reference numerals in the representation are applicable to the text of the specification itself. In this representation we have, of course, the simple outline,

so to speak, of the idea, but nevertheless the whole of its effective principle. The rest of the apparatus is designed merely to accommodate the principle to ordinary phonographs.

Fig. 78 shows a sectional side elevation view

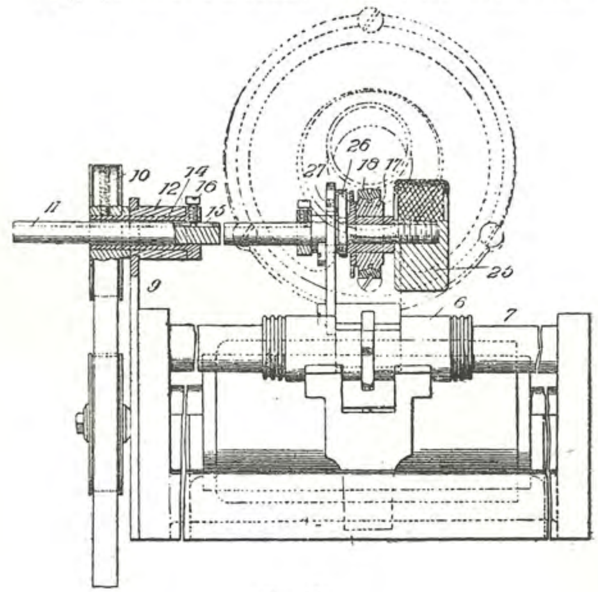


FIG. 79.

of the apparatus embodied in a Columbia Graphophone, known as the B.C. type. In a front elevation view, as shown in Fig. 79, the carriage 6 slides freely on a tube rail 7 inside of which is the feed device, as other types of graphophone cylinder machines were arranged.

The end plate 9 on the left hand of the main frame is extended in height to constitute a support for the pulley and shaft, 10 and 11. The pulley is carried by a sleeve 14, which is arranged to run in a fixed sleeve 12 and which is fastened to the upright end 9 of the frame. Through this rotating sleeve 14 passes the shaft 11. The shaft is provided with a spline 15 cut in it as shown, in which the screw 16 in the rotating sleeve engages. As the pulley revolves it therefore revolves the shaft, at the same time permitting the latter to move freely with the carriage. On the other end of the shaft is attached the friction reel or roller 17, which has a V groove in its periphery, and in which the friction shoe 18 engages. The shoe is hinged in the centre. One end of the shoe is attached to the centre of the diaphragm by a link. To the other end is attached the link which connects to the end of the sapphire lever. A weak spring serves to keep the end of the shoe in contact with the reel. On the extreme end of the shaft is placed a weight 25, which revolves with the shaft and reel. The bearing of the sliding shaft 11 in the carriage is hung on a stirrup 26, which is pivoted on the screw 27. The action of the weight, consequently, is to force down the carriage end of the shaft and to act as a constant pressure in the friction shoe, which effects an adjustment, automatically, of the friction by gravity. The frame or casing in which the diaphragm is mounted is a fixture with the carriage, and the carriage

is not lifted to disengage the stylus from the record, when required. The stylus is pivoted to a weight or fantail, which is pivoted in turn to the carriage, and has an extension which contacts with the lifting cam to lift the weight.

Very strong motors are required to operate these machines, as the power to actuate the friction apparatus is derived from the motor which revolves the cylinder mandril, through an additional toothed wheel which drives the shaft. I have had considerable experience in the management of these machines, and have come to the conclusion that it is bad economy to make an ordinary phonograph motor (however strong) do the double work of revolving the record and of driving the friction shaft. These machines, wonderful as are the results produced by them when in first-class condition, have been a source of much trouble and annoyance to their owners, and the principal of the difficulties has arisen from this defective construction. There are other minor points which require close attention if the best results are to be reached by this class of machine, chief of which are the correct tensioning of the friction shoe, the keeping of the shoe and amber reel free of grease or dirt, by an occasional cleaning with benzine, and the careful regulation of the friction in the adjustment, so that excessive friction will not cause the motor mechanism to drag and govern badly. I am perfectly certain, also, that if the friction shaft had been designed to revolve less rapidly, less power would have been required of the motor to actuate it, and larger volume secured at the same time. A better plan altogether would have been to drive the friction shaft by an independent source of power, and having means to regulate its speed in relation to the revolution of the record mandril.

The other type of Columbia graphophone with friction shoe drive, known as the "B.M.," is a smaller model with a 3-inch reproducing diaphragm instead of 4 inch, as in the "B.C.," and with a simple one-arm (unhinged) friction shoe, which is less satisfactory both in principle and practice. The shoe acts as a band-brake on a similar and smaller amber reel, and the stylus lever is mounted differently. The effects gained by this combination are not greater than those reached by efficient reproducers of the simple type. The friction shoe does not grip and release the reel to actuate the diaphragm motion as in the larger model, but acts as a continuous pressure only upon the reel, the stylus lever movements merely increasing or reducing such pressure alternately.

The "B.C." type of machine is unquestionably the most satisfactory of the two. What I have just observed, however, about the constructional defects of the "B.C." holds good; for since writing my theoretical criticism on this head, I have been to the pains of reconstructing one of these machines, and it will be interesting to note the results I have reached. It occurred to me that the separation of the two

functions of the motor would enable the most important function, that of revolving the record mandril, to be accomplished far more effectively—that is to say, regularly, than would be the case if the motor were required to perform the other function as well, viz., that of revolving the friction reel. The amount of power needed to revolve this friction reel is many times greater than that needed to revolve the mandril. In practice I found that the motor was quite capable of running the mandril evenly, but when the friction attachment was at its proper tension, the governors visibly palpitated and resulted in a "watery" tone effect, which was the more irritating by being magnified. I then set up the body of the machine—that is, the upper part containing the mandril, feed gear and reproducing apparatus—upon the motor of an Edison "Home" phonograph, which I knew governed perfectly, or as perfectly as any motor can be made to govern. I next struck out the toothed wheel which is mounted upon the rotatable sleeve (14), and which meshes with the intermediate wheel between the mandril and feed-screw wheels, in order to be put into motion, the gearing of which was arranged to revolve the friction reel at approximately sixty times per minute. Having done this, I then added an extension member to this rotatable sleeve, so that I could fit a handle to turn it, instead of relegating this function to the ordinary motor mechanism, which I was convinced would not be nearly strong enough for the double purpose, whilst being thoroughly effective for the one. At the first turn of the handle, after the machine had been set going, I realised that the speed of sixty per minute was not the critical speed of rotation, and that an equally good tone was secured by a motion less rapid, even as low as twenty revolutions per minute. I found further that it was not necessary that the reel should be "governed" in its motion; that sudden changes of speed between twenty and one hundred made no appreciable difference in results; whereas the more perfect governing of the mandril, due to the limitation of the motor function, produced a superiority in tonal results which was remarkable. I soon found means to mechanically revolve the friction reel independently, to obviate the trouble of turning a handle, but one way is just as good as another.

These machines, the "B.C." and "B.M.," were constructed, of course, to play the old 100-thread Standard records only; but I have altered a large number of both types to play the newer 200-thread records (Edison Amberols) with very successful results. In most cases I have fitted the differential gear to play either standard at will. The delicate recording of the Edison Amberols is necessarily weak in comparison with that of the older and coarser track, but augmented in volume by means of the "B.C." mechanism and a suitable stylus, they reveal a wonderful change in character

and are reproduced with as great a measure of volume as that of the loudest disc records, while the breadth of tone and clarity of articulation are both extraordinary. Patents have been obtained for the application of the friction-reel apparatus to disc-reproducing machines (see Fig. 80), but I have not been able to learn that any instruments have yet been manufactured for sale, and consequently have not had any opportunity of hearing any practical results. According to the illustration, the adaptation is for "phono" discs exclusively, but there is nothing to prevent the application of the method to the "needle" disc.

The patent specification (5063, of 1906) filed on behalf of the American Graphophone Co. describes Fig. 80 as a detail vertical section, parts being shown in elevation. 1 is the usual casing of a disc form of sound-reproducing machine, containing the usual or suitable driving mechanism for operating the parts, being transmitted through shaft 2. A suitable bracket 3 is mounted on top, on which the reproducer head or casing 4 is secured to bracket, as by screws 5. With reproducer head there is mounted a diaphragm 6, preferably between gaskets. Secured to a shaft 8, extending vertically through the top of the box, is the turntable 9 on which the record is placed. Turning in bearing 11 is a shaft 12, having keyed thereon a pulley 13. The inner end of shaft 12 has an extension shaft 14 connected thereto by a ball and socket joint, with extends in front of and preferably between the face of the diaphragm, and has bearing in a swinging

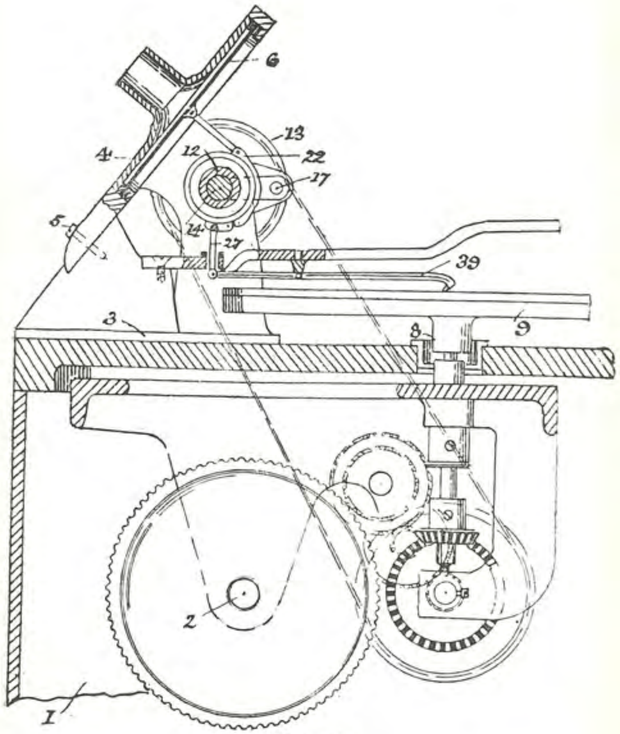


FIG. 80.

arm 16, swinging on a pivot 17 carried in a fixed bearing lug or bracket 18 rigidly secured to the bracket piece or plate 3.

The object of the extension shaft is to allow the stylus arm to move laterally across the record in the usual way, whereas the reproducer is fixed, and does not travel. The arrangement seems to me to be bad, for there must be considerable loss of tone by dispersion in such an arrangement. During the rotation of the record, vertical movements are imparted to the link 27 in such a manner as to be able to turn freely in an horizontal plane, but so that it imparts all movements of the stylus in a vertical plane to the link. During the rotation of the record vertical movements are imparted to the link by means of the stylus and stylus lever 39, and the friction of the shoe 22 upon the friction reel varies in proportion to the amplitude of the vibration, thereby imparting to the diaphragm 6 corresponding vibrations but of magnified amplitude.

I have remarked that there is nothing to prevent the application of the friction principle, and since writing that statement I have occupied myself to construct such an apparatus, and took occasion to make a public demonstration of the machine at the North London Gramophone Society's meeting at Highbury Hall recently. It will be interesting to give some account of its performance.

The general tenor of the criticism offered was that the reproduction was magnificent as far as some records were concerned, but that it was anything but satisfactory with others. It was certainly difficult to imagine anything more realistic than the reproduction of Rachmaninoff's "Prelude in G flat" and Scriabine's "Etude in C sharp minor," piano solos played by Mark Hambourg and issued by the Gramophone Co. Quite apart from their musically artistic execution, the instrument itself seemed to be in the centre of the room; and what struck most of those present was that the very reverberation of the heavy bass strings was brought out with extraordinary fidelity and volume equal to the original, such effects never being heard at all through ordinary sound-boxes. This effect was due, in the main, to the excellent recording, no semblance of "blast" being present. When, however, other less perfect records were reproduced the "blast" passages or notes were relatively augmented, and were intolerable to endure. It is therefore important to select faultless records for reproduction in connection with such an arrangement, and as long as their tone, or *timbre*, is correct it matters little how weak they may be as regards volume, because this can be supplied in the reproducing scheme.

For a long time I have thought that the friction relay is superior to the compressed air relay system, for the reason that a higher quality of tone is more easily reached by that system. It does not follow, for all that, that the compressed air system, with grid valve, is the last word in this field of research, any more than the amber roller and hard rubber friction-

shoe is the last word in mechanical reinforcement. But I am firmly convinced that in one or other of these methods will be found the reproducing means of the future, for the potential advantages of both are far too numerous to be long neglected. I perceive also, in modifications of both these systems, the possibility of eliminating the usual record surface noises, incidental to the contact of the tracking stylus, whereas by the conventional soundbox it is almost impossible to reduce them without at the same time reducing the natural tone quality and volume of the record *per se*. Of course, it could not well be otherwise, inasmuch as the track-scoring is essentially part and parcel of the record itself. By clean workmanship and the employment of improved substances for the record body much may be done to secure greater smoothness and lessen mechanical noises in the travel of the record under the reproducing stylus, and Mr. Edison has already achieved a high level of excellence in this regard by means of superior technical processes. When all has been done that is possible to be done in this direction, I am very sanguine that secondary, or relay, methods in reproducing apparatus will be able to eliminate the remainder. We shall then have advanced a good way in the direction of the ideal.

The further consideration which must be borne in mind is that records which give maximum volume and intensity with a simple soundbox, such as are at present in demand, are already reinforced to the practical maximum in the recording, and will not bear much augmentation. The records of the future, therefore, will be required to have certain well-defined characteristics, such as clean definition, an average breadth of tone, and not excessive intensity, the effort to obtain which invariably puts the recording diaphragm at too great a strain for individualisation in tones. It is really astonishing to me that so little progress has been made in the art of recording for a number of years, seeing how obvious is the need and how limitless the scope for diversion and invention.

If I were asked the question which system of recording is likely to be the ultimate one—that is to say, as between the undulatory and sinuous tracks—I should at once confess my inability to answer it, because I clearly perceive many good points as well as bad ones in both systems. It is very true that the undulatory record is more direct, suffers less in acoustical loss, and is more simple in operation. But the sinuous track lends itself more readily to the reduction of surface friction, and I see no reason why, by improved methods of construction in the recording tool, there should be any more acoustical loss in this system than the other. This loss is painfully apparent at present, to be sure, but that is chiefly because the recording experts find it easier to work by the rule of thumb on certain well-defined lines than subject their work to strict analysis. But progress lies not in that direction.

What promises to revolutionise the whole method of making records with the sinuous track is an ingenious application of the spray principle just lately invented and patented by Mr. Robert Law Gibson, of Philadelphia. There is nothing inherently impossible in the idea, and its success is likely to depend only upon the employment of means properly suited to the end. And if the scheme turns out to be successful in operation, it is very certain that it will mark the greatest advance in the manufacture of records ever made, combining, as it does, the highest theoretical advantages for the recording of sounds, particularly of the composite order, with their harmonics and overtones, such as has never been possible in the manufacture of commercial records before, as well as providing means of a practicable character to greatly reduce mechanical friction in reproduction. In addition to this, the manufacture of records will become a more simple matter, and at the same time less expensive, in the allied processes.

It is well known that most of the trouble in connection with "noisy" records—that is, those which emit disagreeable hissing sounds in being mechanically reproduced — arises from causes incidental to the use of metallic soap blanks. The difficulty of securing a perfectly homogeneous compound, as well as that of preparing its surface by shaving, or any other means, to obtain a brilliant or perfectly smooth face without fracturing the material itself, have always been considerable, and only the greatest care in saponification and chemical mixture on the one hand, and skilful manipulation of mechanical means on the other, have contributed to effect anything approaching to the desiderata in this regard. Then, after all this has been satisfactorily accomplished, there yet remains a further source of surface noises in the circumstance that the track groove (which, of course, is required to be cut into the substance of the blank simultaneously or coincidently with the engraving of the sound wave sinuosities) has of necessity to be cut by the recording stylus, which is not rigidly held in a fixed position relatively to the surface of the blank, but is attached at its other extremity to a resilient diaphragm. The mere passage of the stylus over the blank in these circumstances causes what is known to engineers as a "chatter," which resolves itself into a continuous series of minute undulations, and which are registered in the track and are translated into the well-known hissing noises in the reproduction, as something foreign, or altogether apart from the recorded sounds proper. As I have already remarked, the employment of great circumspection in these allied stages of manufacture may do a great deal to reduce these objectionable features, but there is a limit to which this technical supervision can be practically applied, and it must never be forgotten that the causes of the trouble are inherent in the system of cutting the blank.

It is important also to point out that in the

present system of recording by cutting into the substance of the blank it is next to impossible to record the delicate overtones of sounds with any degree of accuracy, for the simple and obvious reason that the contact of the stylus with the blank has the effect of damping the recording diaphragm; and the feeble character of the minor vibrations is insufficient to actuate the diaphragm completely with this clog upon it. The average record, therefore, presents itself as a coarse outline only of what the actual vibratory activity of the diaphragm would be if left entirely free to respond.

Now the superiority of Mr. Gibson's system will be at once obvious when it is realised that he abolishes the ordinary soap blank entirely; and instead of cutting the record into any substance whatever, he reverses the process and deposits an inverted track of molten wax upon a previously surfaced disc through an extremely small nozzle connected to the recording diaphragm, which becomes wave-like as the diaphragm directs it upon a previously prepared revolving plate or disc of metal, glass, or any other suitable material, the lower temperature of which will immediately congeal or fix the wax stream as soon as it is deposited.

It has been pointed out that in the commercial manufacture of records it has been found necessary or desirable to make a master matrix from the original record, which is only used for the purpose of producing matrix duplicates for actual work in the presses. In order to get an exact replica of a master matrix, an intermediate process is necessitated, in the production of a "mother" matrix, which is a facsimile in metal of the original record, and being a positive, from which the subsequent negatives can be obtained. This is electrotyped from the first negative, or master matrix, in a manner similar to that of producing the master matrix from the original wax. And in the same way the secondary or duplicate working matrices are obtained from the metallic positive, or "mother" matrix. It will be understood, from the description of Mr. Gibson's method, that his original record is to all intents and purposes like the ordinary master matrix, in cameo, as distinguished from the intaglio form of the ordinary "mother" matrix. This advantage alone dispenses with one of the three separate depositions required in the old system, and reaches the same end by two. That is a clear gain, not only in the matter of time and also in the saving of expense in materials, but in the elimination to this extent of the surface roughness which also invariably follows from every deposition of metal in grains.

The practical application of the scheme is described in the British Patent Specification, No. 109,237. The most important factor in the process is the ejection of the fluid medium finer in section and volume than would be required to constitute the record ridge, as the latter must be built up to prevent spreading and to chill rapidly; and this can only be accomplished by

enormous pressure being brought to bear upon the fluid medium in order to force it in a regular stream through the microscopic orifice, and by regulating its ejection so that it takes place at a velocity substantially greater than the rotating speed of the receiving plate. In this way the form of cross section in the ridge itself may be varied.

The ordinary disc record with a sinuous track assumes a V form in cross-section, and it may be regarded as a difficult proposition to spray or emit a stream of molten wax through any kind of orifice that would deposit itself with perfect regularity in an inverted V form. Nothing could be easier in the case of the U form of track, however, for such a stream would automatically assume that contour when expelled by pressure through a cylindrical tube upon a plane surface in motion. And my experiments in track forms have convinced me that it is very desirable to modify the conventional V form of the sinuous disc, inasmuch as this particular form of track necessitates the employment of a very pointed stylus (e.g., the steel needle) for reproducing purposes, and this element alone is responsible for a great deal of objectionable surface noises caused by the rapid wear and tear of the record, quite apart from the other causes already enumerated.

CHAPTER XX.

CONCLUSION.

From the foregoing observations with regard to relay reproducing schemes, we are bound to consider how best to work out the primary essentials in the making and manufacture of records conformable to the requirements of this system. It will be no longer necessary, then, in the case of the undulatory or "phono-cut" records to utilise track width for the purpose of securing the maximum breadth of tone. The incident of amplitude in the sound waves registered in the record becomes also of smaller importance. The finer the tracking reproducer stylus the better for all purposes, particularly for securing clean definition and reducing frictional disturbance. The sinuous or "needle-cut" records are already reduced to the practicable limit in this respect, and in the year 1908 I filed a Provisional Specification (No. 25,057) at the British Patent Office setting forth a novel method of engraving undulatory records by using a V-shaped stylus and making a V-shaped track in cross-section, thereby giving increased sensitivity to the recording diaphragm and permitting of at least double the amount of recorded matter to be registered in the same space as was possible by the employment of the usual track of U form in

cross-section, without any loss of surface friction and therefore of volume. This latter consideration need no longer weigh with friction reproducing methods, but the economy effected in the necessary restriction of track width by the use of the V track is likely to be of some utility in the lengthening or cheapening of records. Either the standard sizes of discs may be reduced, or, if retained, may accommodate much longer selections of music. For friction relay reproduction the

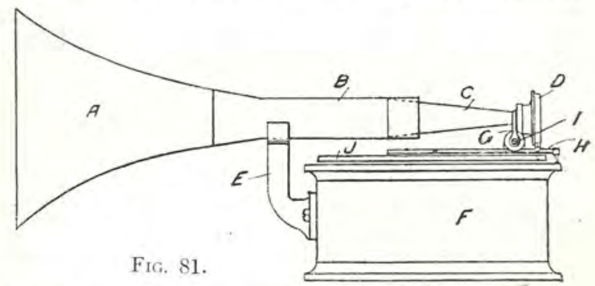


FIG. 81.

V-cut undulatory record is peculiarly suitable, from a mechanical point of view, on account of the more certain tracking of the reproducing stylus, in addition to the form, which ensures that the most delicate overtones of sound can be recorded.

It would be a decided advantage in favour of the friction relay reproducing system for discs if reproducing machines were constructed with a traverse turntable after the manner of up-to-date recording machines, so that the heavy and complicated reproducer and gear could be stationary and the record be brought towards it in a straight line, instead of resorting to the bad mechanical arrangement of a tone-arm, which in its traverse across the record in following the record spiral is bound to describe an arc. A part arrangement of this character for ordinary simple reproduction has

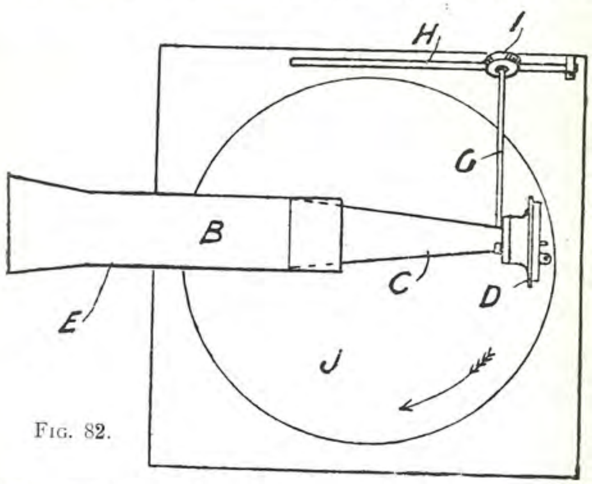


FIG. 82.

been worked out and patented by Mr. William Grimshaw, of Prestwich. Fig. 81 shows a side elevation view of the scheme, and Fig. 82 the plan view of the same. Fig. 83 shows a part of the mechanism, which is a free reel to keep the sound-box from being diverted from the straight line by the stress of the curved track of the record in rotation, which otherwise controls its lateral displacement. A tone-arm is

provided, consisting essentially of two tubes of suitable diameters, one sliding inside the other in a transverse direction to the sound grooves. The larger tube is connected at one end with the horn, and is of uniform size and section for a distance approximately equal to the width of the recorded surface. The smaller tube is preferably tapered in section, the sound-box being attached to the small end thereof, the other end being made to slide easily in the uniform portion of the larger tube, which is rigidly supported on the cabinet. In the type shown in the figures, *A* is the horn, *B* is the

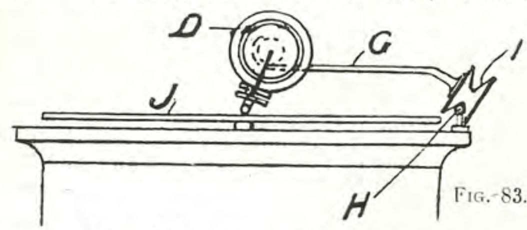


FIG. 83.

larger tube, *C* is the smaller tube, *D* is the sound-box, *E* is the tone-arm support, and *F* is the cabinet. *G* is an arm fixed to the tube upon which the sound-box is mounted. *I* is a pulley or reel sliding freely on the rail *H*, and permitting a vertical movement of the sound-box as well as a movement in a direction transverse to the recorded groves. *J* is the turntable which, of course, rotates in the direction of the arrow as usual.

Inasmuch as records are made through the medium of a feed device which effects the lateral displacement of the recording stylus in a straight line, it becomes a matter of importance to reproduce such records by means of a similar method in order that the reproducing diaphragm shall always be at right angles to the track line. In describing an arc by the use of the conventional tone-arm, the sound-box diaphragm is more or less at a tangent from the rectilinear position, and, although the loss of tone by this circumstance appears to be negligible in practice, the tone-arm must be condemned as a mere mechanical makeshift. The loss of tone is negligible, because no comparison can be possible through the same tone-arm; and even with a comparison set up with the two types of machine, it is not easy to justly determine the question of superiority on account of the several other factors entering into the respective results.

It would be perfectly simple to construct a recording machine so that the recording tool described an arc, in which case the foregoing remarks would scarcely be *apropos*. The record sinuosities would then be somewhat changed in their aspect to the reproducing diaphragm. A patent was issued to Mr. Eduard Wawrina, of Vienna, in 1908, for a type of mechanism to effect the regular lateral displacement of the tone-arm for recording purposes. Fig. 84 shows a side elevation view partly in section, and Fig. 85 shows part of the plan view. There are obviously other methods by means of which a similar movement could be effected, but this is simple. In operation, the mainshaft being

revolved as usual takes along the feedscrew 2, which actuates the screw-wheel 3 and, through the intermediary of axle 5, the pinion 6. The segment 7, which engages with said pinion 6, is thus taken along in longitudinal direction, so that the recorder is moved towards or away from the centre according to the direction in which the screw-wheel 6 is turned. From this

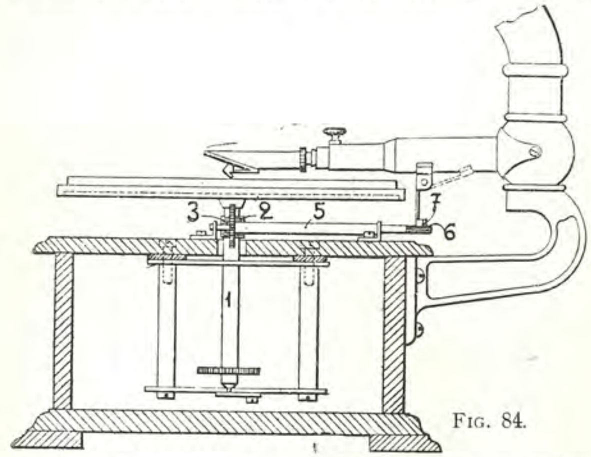


Fig. 84.

combined motion it results that the recorder describes a spiral. The distance between the threads of the spiral described can be regulated according to requirement through a corresponding adjustment of the gearing. Instead of the feedscrew a suitable system of toothed wheels could be provided, and the pinion 6 could be replaced by a friction wheel.

Another mechanical inferiority of the disc form of record is the varying linear speed of the recording surface presented to the recording tool, which is responsible for a gradual reduction of tone as the record proceeds by reason of the gradual reduction of wave-lengths of similar tone pitches. If we take, for example, a record and measure the wave-lengths of a

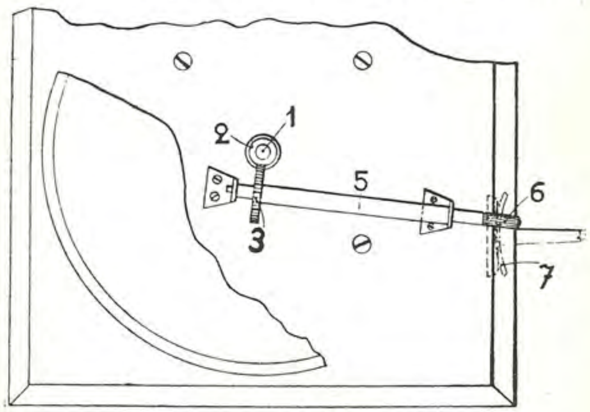


FIG. 85.

given note of a given instrument at the outer radius of the disc, and measure that of a similar note towards the centre we shall find that it is considerably shorter, and this is necessitated by the equal rotation of the disc. If the linear speed could be made equal by a gradual acceleration of the speed of rotation, the sound-waves of a given note would be equal in length, and this would ensure that the sound would be equally brilliant at the end as at the

beginning of a record. The cylinder form of record suffers no defect of this character, because the linear speed is necessarily equal. If it is said that the cylinder record is in other respects, or in some other respects, inferior to the disc record, permit me to point out that the form has nothing whatever to do with the results in reproduction, and that it would be just as easy to record cylinders by the sinuous as by the undulatory method, in which case precisely the same tonal results would be obtained. I am assuming, of course, that the linear speed of the cylinder would be equal to the average linear speed of the disc, which would be governed entirely by calculation based on the diameter of the cylinder.

The great difficulty which besets the inventor and innovator is the requirement, commercially, of conforming new schemes to established conditions. Even supposing that an improved disc record were produced having an equal linear speed, as pointed out, it would be imperative to furnish also a reproducing machine with a differential turntable motion to correspond with that of the recording machine with which such records were made. The added expense of such a machine would deter the great majority from purchasing the improved records, and therefore the prospect of commercial success attending the advent of such an innovation would be exceedingly doubtful, quite irrespective of its superior merit.

An innovation which would be equally doubtful of success is one which was suggested by Mr. Bawtree some years ago, which was a record in the form of an endless band running over two cylinders. I must confess that this scheme strongly appeals to me on account of its advantages over any other form hitherto adopted. In considering such propositions as these it is first of all necessary to enquire into their technical possibilities, and I see nothing in the allied processes of record manufacture to put Mr. Bawtree's proposition out of court. The master record could be made, with either kind of track, in the cylinder form, and the blank might assume a very large diameter with any desired length. The machinery for making records in the cylinder form, say, three feet in diameter, need not alarm the general public on account of the storage room needed to accommodate records of such proportions, because the "master" records would never be seen outside the record factories. But in order to obtain an endless band type of record it is imperative to make it, in the first place, as a cylinder of large dimensions, which would have to be recorded at a relatively lower rate of revolution. Having secured the master record in this form, it becomes a comparatively simple matter to produce a metallic negative of the same by the known method of electro-deposition. Celluloid is an eminently suitable substance for the duplicates, and after being pressed by steam and air, as set out in an earlier chapter, it would be sufficiently flexible to permit of being tightly drawn over rollers or mandrils set in juxtaposition. The most convenient form of

reproducing machine for such a record would be the cabinet form, with the reproducing mechanism mounted over an upper roller, so that the band could be stretched over a lower roller in the base of the cabinet by means of a suitable adjustment. The upper roller should be covered with a rubber or similar surface as a bed for the band, and, if found desirable, perforations might be made at either edge of the record to ensure against the danger of slipping. But in order that the record section immediately beneath the reproducing stylus should be kept firm and in close contact with the upper roller, it would be necessary to employ a more powerful driving mechanism than the spring motor in common use, and a well-governed electric motor, deriving its current from ordinary lighting circuits, should answer this purpose. The best method to govern an electric motor efficiently is to drive from a train of wheels with governors or worm gear, as the case may be, the connection from the motor armiture spindle to the governor apparatus being made by a short length of steel cable which is considerably flexible. Any small oscillations in the current are thereby absorbed, and the momentum of the cylinder or turntable is sufficient to reduce any such fluctuation of current to the practical minimum.

The use of the sound-reproducing machine in connection with the cinematograph has not been extensive up to the present time, owing to the complicated character of the combined apparatus and to the difficulty of making sound records of sufficient intensity and reproducing length. The scheme referred to of making records on an endless band of practically indestructible material would bring into view greater possibilities of this combined mechanism. Also advances in relay reproducing methods would make good, in a large measure, the defect of the ordinary gramophone in large halls—its lack of carrying power. I had an opportunity of being present at a demonstration of Mr. Edison's synchronised cinematograph and phonograph when first brought to this country, and it may be interesting to note that the phonograph was in this instance reinforced by frictional means, the effect over a considerable area being remarkably realistic.

The synchronising of the photographic film and the sound record is, of course, the fundamental requirement in a combination of this character, in order that the action shall be suited to the word, so to speak. It will be understood that the optical machine must be actuated, in its reel motion, by a well-governed motor mechanism to ensure that regularity and periodic displacement in the film which is of so much importance with respect to the sound record in its motion under the reproducing stylus. The rate of displacement of both need not be coincident, but the ratio of speeds set up in the simultaneous recording must of necessity be maintained in the combined reproduction, or no synchronism will take place.

For the purpose of obtaining synchronism between the cinematograph and phonograph

without having any connection between them, a pointer has been employed in various ways by different inventors. The Barker and Jeapes scheme attaches the pointer to the phonograph, and this is photographed on to the side of the film when the picture is taken. The reproduction of the pointer is projected near the phonograph, so that it becomes a simple matter to regulate and maintain the same relative linear speed of film and record.

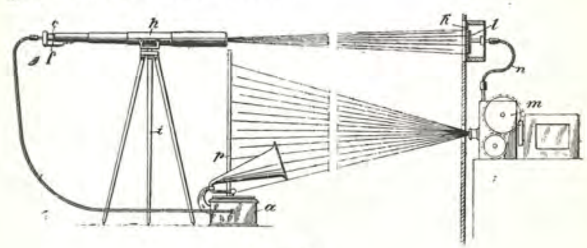


FIG. 86.

The Duskes scheme employs a visible sign moving with one of the machines and transmitting it in the form of a shadow or image to a visual sign moving synchronously with the mechanism of the other machine, so that the operator, by controlling the action of one machine, can secure synchronism in the other. In Fig. 86 a flexible shaft *b* rotates a glow lamp *c* provided with a transverse filament or bar, and the light is projected by a telescope *h* to a ground-glass plate *k*, where the shadow or image is kept in angular adjustment with a pointer *l* driven by the cinematograph. As a variation, the device may be reversed, the image being projected from the cinematograph to a disc rotated by the phonograph. There are manifestly many other ways in which this synchronism might be worked out, and as long as the desired object is attained it matters little what precise means are employed for the purpose.

. . . .

In bringing these pages to a close, I trust that I have, in some small measure, succeeded in this humble attempt to describe the various manufacturing processes employed in the mechanical reproduction of sound. The subject is one which is difficult to translate into words, bristling, as it does, with many technical intricacies which language itself sometimes seems utterly inadequate to express. It is this very aspect of complexity which makes the subject so engrossing to the inventive mind and so interesting to the layman; and I shall feel amply rewarded for the labour I have spent in the preparation of these chapters—which I am conscious are all too brief—if I have been able to arouse a larger or more comprehensive interest in the subject, as well as to engender, perhaps, an increased effort on the part of others towards its fuller investigation.

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