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GRAMOPHONES
Acoustic and Radio

Compiled by
G. WILSON

With 64 Diagrams and Illustrations

GRAMOPHONE (PUBLICATIONS) LTD.
10A SOHO SQUARE, LONDON, W.1.

PREFACE.

A simple guide to the mysteries of gramophones and radio-gramophones which the ordinary man can understand without too much delving into intricate technicalities has long been needed. An attempt to fill the gap in so far as the ordinary acoustic gramophone is concerned was made in 1928 in the forerunner of this little book—*Novice Corner*. But this is now out of print and in view of the developments in both acoustical and electrical reproduction that have taken place since it was published, it has been thought well to take its subject matter as the basis of a much more ambitious publication rather than attempt to revise it in matters of detail.

The present volume has been compiled by Mr. G. Wilson of the Technical Staff of *The Gramophone* mostly from articles and technical notes that have appeared in the columns of that magazine. It is not intended to be a complete technical treatise, nor does it give any account of the romantic history of the gramophone. But, on the other hand, it is believed that both the gramophone fan and the ordinary user will find in it simple and direct answers to all the questions that puzzle them from time to time.

Thanks are due to various firms for the loan of blocks, etc., with which to enliven the text; and in particular, to The Gramophone Company, the Marconiphone Company, the Columbia Graphophone Company, F. E. Godfrey Radio Ltd., E.M.G. Handmade Gramophones Ltd., W. J. Bond & Sons, Amplifiers Ltd., Baker's Selhurst Radio, Collaro Ltd., and E. M. Ginn "Expert" Gramophones. And above all to: W. R. Anderson, W. A. Chislett, C. M. Crabtree and C. H. Warren for their contributions of best record lists.

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CHAPTER I.

BUYING AN ACOUSTIC GRAMOPHONE.

Acoustic gramophones can conveniently be classified under four different headings: Portables, Table Models, Pedestal Models, External Horn Models. Broadly speaking it can be said that the larger the instrument the better chance it has of faithfully reproducing what is on the record. Do not, however, misconstrue the meaning of the word " large " ; a cabinet model in which considerable space is given over to the storage of records, so restricting the size of the horn, will function no better than a table model incorporating the same size of horn. It is, to a great extent, the size and design of the horn that governs the range and quality of reproduction. The tone-arm, sound-box and motor play important parts as we shall see later on; but the size and shape of the horn have the most to say in every act.

Have you ever listened to a portable gramophone and then immediately listened to the same record on a cabinet model? If so you cannot have failed to notice the increased depth and breadth of tone given by the latter. Even if the same type of tone-arm and sound-box is fitted to the larger instrument, the disparity will still be marked. This is because a small horn is incapable of passing the lower notes of the music. Apart from the effect on reproduction this is one of the reasons why record wear on a portable is more acute than on a more generously designed gramophone. It is also one of the reasons why the points of non-metallic needles—fibres and Burmese Colour needles—break down more frequently on a portable. In the interests of portability compromises have to be made at every stage. Not only must the horn be small and light, thereby making it virtually impossible to carry out a design which would ensure a large musical range, but the motor has to be small, the tone-arm fairly short and of thin gauge and the sound-box has to be contructed in such a way as to give a forced semblance of volume. All these things are severe restrictions imposed on the maker by the mere size and weight of the instrument. A further disability arises from the fact that one naturally expects to pay much less for a small portable instrument than for a larger cabinet or even a table model ; and the difference that has become established in market value is not by any means proportional to the difference in manufacturing costs. In view of these considerations it is rather a matter for surprise that a portable gramophone can be so efficient as many of the modern ones undoubtedly are. They definitely have a place in the gramophone gallery, and a very popular place, albeit but a humble one from the technical and musical points of view.

Table type gramophones have the advantage of a larger horn, and usually a longer tone-arm, so that the tone is broader, the range longer and record wear slightly less. Cabinet models, by virtue of their larger acoustic system, are more efficient still, but naturally are not so easily transported from room to room. The modern external horn instrument certainly has aesthetic disadvantages but is usually superior to any other acoustic type for the reason that the designer has fewer spatial restrictions within which to work out his ideas. The tone has more body and is more forward, and the range is greater.

It is necessary to make these distinctions clear to start with since they are fundamental to any proper appreciation of the matter. Other things being equal a gramophone with a large horn, properly designed, whether of the internal or external type, is bound to be better both in quality and in the matter of record wear than a more compact instrument. If you must have a small instrument then you must definitely resign yourself to a somewhat lower standard of reproduction—particularly of heavy records, whether of orchestral music, dance music or even of pianoforte music.

But mark the qualification in the words " properly designed." There are still far too many makes of instrument that are imposing in appearance (and salesmanship !) and definitely inferior in performance. The furniture shop gramophone is usually to be found in this category. The " nearly new " gramophone, of doubtful paternity advertised for sale " with six records " by Mrs. Somebody or other in the small ads. section of the daily press, is often a patent fraud. Yet some people are taken in by it ! Remember that buying a gramophone is but the first expense and that before long you will want to buy more and more records and to keep them in good order. A badly designed instrument may easily massacre records ; so that a little care in your first venture and possibly a little extra outlay to ensure that you are buying a good instrument may save pounds later on. You cannot go far wrong if you stick to the makers who advertise regularly in *The Gramophone.* Makers of inferior products either do not advertise them in this way, or if perchance they do slip in now and again their zeal does not survive the first test report !

FIG. I.—The E.M.G. Mark XA Gramophone.

Now for some practical tests you can carry out for yourself. First of all make up a list of records you would like to hear. Include in it orchestral records, chamber music records and piano records as well as vocals. A good dance band record is also advisable whether you are fond of such music or not; for it can show up many a fault in a gramophone. The vocal records chosen should, if possible, be of artists with whose voices you are familiar so that you can judge if the reproduction is faithful to the original. If, however, this is your first venture into the world of records then the list given below will be helpful. In any case read it before proceeding to hear the instruments you are going to hear in order to refresh you memory on the various points to listen for. First of all have an orchestral record played to test the general efficiency. Satisfy yourself that the tone is full-bodied, that the reproduction is a reasonably accurate portrayal of the original instruments and that the tone is crisp, clean and detailed. It matters little in what sequence you choose to hear the various types of record but make a point of hearing each record on more than one instrument before hearing the next record. Some of the tests should be made with the lid of the gramophone open and you should listen carefully to the mechanical noises made by the needle in the groove and also for any obtrusive mechanical noises made by the motor. If the needle buzzes, rattles or chatters it is a sign that the instrument is not reproducing properly and that records will be quickly worn. Another test is to see whether a fibre needle point will stand up on a heavy jerky passage.

TEST RECORDS.

Orchestral.—H.M.V. D 2048, Tenth side: *Berlioz Symphonie Fantastique.* This is an excellent test record since one has an opportunity of hearing massed strings, brass and wood wind instruments and tympani in turn. Listen carefully to the definition and to the pizzicato of the strings. The latter half of the disc will make a poor sound-box uncomfortable. This record is from the H.M.V. Connoisseur Catalogue and in case the dealer does not stock records from this, here is another very fine test record excellently recorded: Columbia LX 156: *Götterdämmerung—Funeral March,* part 2. Here again is variety of colour, fine orchestral tone, plenty of bass and drum work.

Chamber Music.—H.M.V. DB 1223: *Cortot, Thibaud and Casals* playing *Haydn's Trio No. 7 in B flat major,* op. 97 (The Archduke Trio). This is a splendid example of chamber music and gives an opportunity of judging both string and piano tone. The latter should not "whine" or be "pongy." Take particular notice of definition on the second side.

Piano.—Columbia DX 278: *Gieseking* playing *Beethoven's Sonata in D Minor,* Part 4. Here is excellent piano tone and recording. At no time throughout the playing of this record should there by any wooden tone nor should there by any unduly resonant bass notes. If there is a tendency for the piano to whine (change in pitch) suspect the motor. A motor with insufficient power will vary in speed thereby causing a variation in pitch. Natural piano tone is the essential thing to listen for.

Vocal.—H.M.V. DB 1317: *Toti dal Monte* singing *Ah! Non credea mirarti* from Act 3 of *La Sonnambula.* This is exquisite recording and the vocal tone is simply lovely when reproduced properly. Listen carefully to the articulation. Then turn the record over and listen for delicate interlacing of voice and orchestra in the opening of the excerpt from *Falstaff.*

Columbia DB 524: *Harold Williams and the B.B.C. Male Chorus* singing *Wrap me up in my tarpauling jacket* and *The Lincolnshire Poacher.* On a good instrument the fullness of tone both of the singing and the piano accompaniment is most impressive. There should be no blasting or needle chatter. If perchance you are fond of operatic ensembles listen carefully to the orchestral and vocal definition and also for needle chatter on Parlophone R 20085: *Finale Act 2* from *Die Fledermaus* sung by Lotte Lehmann, Karin Branzell, Grete Merren-Nikisch, Richard Tauber, and Waldemar Staegmann.

On the technical side look to the following points:

(1) That the motor runs silently and smoothly and will play a full 12 inch record without wavering. There is nothing more annoying than a faulty motor.

(2) That the tone-arm works freely; but neither the back pivoting nor the forward joint should rattle.

(3) That the sound-box diaphragm is intact. Look on the inside as well as the outside, particularly at the point where the stylus bar is fastened to the diaphragm.

(4) That the error in alignment is not excessive.

With regard to this last point you may wonder what "alignment" is. The explanation on Page 19 is reprinted from *The Gramophone*, and if you can master it, so much the better. If you cannot, you must, in buying a gramophone, or a radiogramophone for that matter, use a little bluff and ask firmly "What is the error of the needle-track alignment?" There is now no excuse for a salesman to be ignorant of this, but if your question puts him in a quandary then you may be sure you have gone to the wrong place, and you should leave quickly. If, however, he answers you intelligently and proceeds to prove to you that the alignment is good by means of a protractor you may be pretty sure that he is trying to sell you a reliable instrument.

CHAPTER II.

HOW A GRAMOPHONE WORKS.

In an ordinary gramophone the needle which tracks in a record groove imparts vibrations, through a metal arm known as a stylus-bar, to a diaphragm, which is mounted in a sound-box. The diaphragm converts the mechanical vibrations into air-pulses and thereby creates sound-waves. The function of the tone-arm and horn to which the sound-box is attached is to "load" the diaphragm, *i.e.*, to make it do more work in moving through a given distance. In the open air a diaphragm can be moved very easily, but when it is loaded by a horn it takes a lot of energy to move it, and this energy (or part of it) is what we hear as sound. It is in this sense, and this sense only, that the horn acts as an amplifier: it causes the diaphragm to extract more energy from the gramophone motor, through the record, and it transfers a greater proportion of the energy to the outer air. It is important to notice that all the energy comes from the motor; that is why we need a strong motor. The record acts like a sort of valve admitting energy to the diaphragm at varying rates and in varying amounts. To change the simile, it is like a policeman directing the traffic; the motive power comes from elsewhere.

Another function of the horn should also be noticed. In the open air a diaphragm will respond more easily to certain vibrations than to others. You know that when you strike a particular note on a piano some ornament or other may start buzzing. That is because the ornament responds very easily to the particular vibrations of which the note consists; its "natural frequency" is the same as that of the note you struck, and the two are then said to be "in resonance" or "in tune." The same principle applies to a diaphragm, and indeed to every part of the sound-box. They will respond to certain notes much more easily than to others. They have "resonances." But as soon as you attach a horn to the sound-box the resonances tend to be "damped out." If the horn is big enough and is properly designed none of the resonances may be perceptible to the ear. That is, the apparatus becomes more equally responsive to all notes. This, of course, is what should be aimed at. The perfect gramophone would respond to all notes in the scale equally. The difficulty is that a horn loads a diaphragm much more effectively for high notes than for low ones. For this reason a very large horn—certainly over 12 feet long—would be needed to load a diaphragm sufficiently to enable it to respond evenly to *all* the notes that are recorded nowadays. And if you attempt to use such a big horn with an ordinary gramophone, the loading is so great that very few sound-boxes are able to extract enough energy from the record. The sounds seem to hang inside at the back of the horn. In current jargon, the tone is "backward" or "boxed up."

Chapter III.

USING A GRAMOPHONE.

Position.

If you are really keen on getting the utmost enjoyment from your gramophone it will repay you to carry out a few experiments regarding its position in the room. Try it in different positions and listen to it from your usual chair. It may sound best in a corner, or even facing a corner, or in a conservatory if you have one leading from your sitting room. If it is a cabinet instrument try to avoid placing it in close proximity to heavy carpets, rugs, etc. These, being absorbent, have a decided effect on the forwardness and brightness of the tone. But remember that the final position should be such that the motor will not get cold in winter.

It should also be noted that the temperature of the room and the humidity of the atmosphere have noticeable effects on the quality of sound that you hear in a room. Indeed the Gramophone Company attach so much importance to these two points when recording that they went to great expense to install special air conditioning plants for the new studio at St. John's Wood so that the temperature is kept constant and the actual atmosphere is of a uniform humidity.

Side Pressure.

Having at last selected the final position you will minimise any tendency for records to wear by making sure that the instrument is level. You may perhaps have noticed when the needle is placed on the outer (blank) rim of a record that it tends to be drawn into the groove of its own accord; or, on the other hand it may tend to run off the record altogether. In either case, there will be a side pressure on the groove when a record is being played. This is one of the things which lead to record wear. It may be due to one or two causes. For instance, the back bearing of the tone-arm may not be exactly vertical, so that the tone-arm has a tendency to swing one way; or the gramophone, or the floor, or the table on which it is placed may not be level, which will produce the same effect. But even if these are exactly right, there will be a slight tendency for a freely-moving tone-arm to swing inwards across the record. This is due to the effect of the friction of the record on the needle point. The more freely the tone-arm moves across the record the more pronounced this effect will be. Fortunately it is quite easy to correct any tendency for side-pressure whatsoever the cause of it may be. Place a 12 inch record on the revolving

Fig. 2.—Another type of external horn gramophone—The Cascade II.

turntable and gently lower the sound-box (with needle) first on to the outer blank rim and then on to the unrecorded portion just outside the label. Choose a record, if possible, which has a lot of blank unrecorded space (or the unrecorded side of an old single sided record, if one is available). Parlophone R20142, Richard Tauber singing *For you Alone* and on the reverse side *Heinway* (Always) will serve quite well for this purpose if you happen to possess it. In any case it is Tauber in a popular mood and your money will not be wasted if you get it for this purpose in the first instance. Now note if the sound-box etnds to swing inwards or outwards. If it swings inwards then you must put a little packing (paper or bits of cardboard) under the feet of the gramophone either at the left or at the front—the former if the tendency for inward swing is greatest at the inside of the record and the latter in the opposite event. If, perchance, it swings outwards, then packing on the right or at the back may be required. A certain setting will be found so that there will be no inward or outward swing anywhere. That is the state of affairs we are aiming at for then there can be no side-pressure on the record grooves. It is just possible, however, that the cabinet itself will not be level; in some known cases as much as ¾ inch of packing has had to be placed under the feet of one side of the cabinet so that it appeared to be in a state of unstable equilibrium or in other words ready to topple over upon the slightest provocation. This is due either to the board on which the tone-arm is mounted not being set square with the body of the cabinet, or to the tone-arm not being set up properly so that the back pivot is out of perpendicular. This should be pointed out to the dealer at once who, no doubt, will rectify it without quibbling. If your instrument is a second-hand one then you must correct it yourself either by resetting the board or by remounting the tone-arm. In this event be careful to see that the joint between the neck of the horn and tone-arm is absolutely air tight.

From the Beginning.

Now you can prepare to enjoy your gramophone to the full. Wind up the motor gently and steadily, while the turntable is revolving—not while a record is being played. Do not even wind it up till it comes to a stop with a jolt: you may break a spring; but (if it is a double-spring motor) try to use it so that all parts of it get their share of the work. Find out how many sides it will play without failing in speed; if it plays three 12 inch sides, for instance, let it do so and do not wind it up between each record. This will ensure that the springs are evenly worked. A modern motor will give good service if the springs are not strained. Having wound it up and having put a record on the revolving turntable and a needle in the sound-box socket, lower the needle on to the outside blank rim of the record and gently guide it into the first groove. *Close the lid* and sit down.

Get the Habit.

A gramophone, like any other mechanical arrangement needs periodic attention and it is better to form some sort of system right at the beginning rather than be sporadic regarding the care of it. Here are the golden rules:—

(1) Keep it clean.

(2) Lubricate the necessary parts—the motor, the tone-arm, joints—at least once every three months. Don't drown them in oil; a drop or two is sufficient.

(3) Don't hoard used needles. They may get into the motor mechanism or between the cabinet and the horn thus causing a rattle.

(4) Do not forget to look at the point of each needle before you use it, to make sure that it is not already blunted or even broken off. In every box there may be one or two bad needles which, if used, will probably ruin some of your records with one playing.

(5) Never give the turntable a flick with your hand in order to speed up the motor. You may strain the governor.

(6) Keep your records scrupulously clean.

(7) Don't wind up the motor while playing a record.

CHAPTER IV.

NEEDLES.

This is a tricky subject. The needle is really part of the sound-box and for any particular sound-box there are certain types of needles which suit it best. The difficulty is to find out which. Trial and Error is the only method. It is false economy either to buy cheap needles or to use them more often than the makers recommend. Indeed, with the so-called "semi-permanent" needles it is wise to be on the safe side and not to persevere too far with one point. A useful reminder from one of the makers is as follows: "Do you know that it takes nearly a month to make a gramophone needle, yet the actual working life is only five minutes at the most? In the course of playing a 12 inch record, the needle travels along a track about 740 feet long, carrying a weight of 3½ oz. on the extreme point, which represents over 12 tons to the square inch: can you wonder at the care that is necessary to make a needle stand up to these conditions?" On modern gramophones the actual weight on the needle point is nearer 5½ oz. than 3 oz. so that the tonnage per square inch is considerably increased.

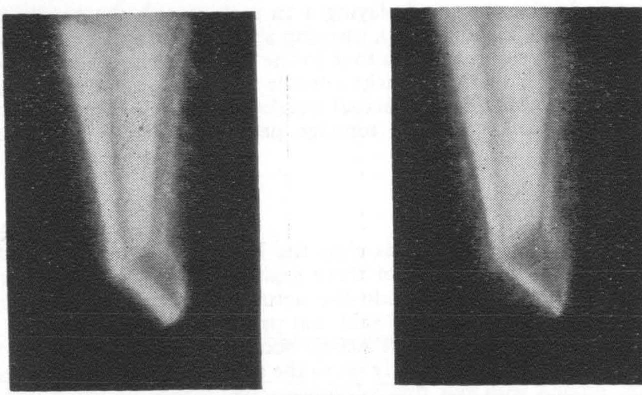
TYPES OF NEEDLES.

(1) *Semi-permanent.*—In this class the H.M.V. Tungstyle is probably the best known. It is made in three grades—soft tone, loud tone and extra loud tone. In each grade the actual point is made of tungsten wire—a very hard metal. It is said that provided it is not removed from the sound-box or turned in the needle socket after once being used and provided that it is lowered gently on to the smooth outer rim of the record and then guided into the first playing groove, each tungstyle will play 150 records! A much safer number would be 30 *sides*. The tone given by these needles is brilliant but with many sound-boxes is apt to impart a metallic quality to strings.

Other semi-permanent needles which are still very popular are the Edison Bell "Sympathetic Chromic" and the "Euphonic" sold by The Murdoch Trading Co. These are very thin and have to be used with a special "grip." By varying the amount of needle projecting from the grip, the loudness is governed to a certain extent. A short projection gives a loud tone and more length gives a softer tone, but this is accompanied by a hiss. Badly worn records often gain a new lease of life with these finely pointed needles.

Then there are the Chromogram and Pyramid "Talkie" needles. The former is made of Chrome steel and is in three grades: medium tone, semi-fine and a fine tone "Grip" needle which is similar to the Sympathetic Chromic. The makers' advice regarding the useful life of each point is significant, for, after stating that each will easily play ten records, a rider is added saying that for costly records a limit of six records is often preferred. The medium needle is capable of giving a very fine tone and was, at one time used by Mr. Christopher Stone practically to exclusion of every other kind. Recently, however, he has been using the Pyramid "Talkie" needles, which he finds excellent. The Expert Committee of *The Gramophone* carried out some very stringent tests with these needles and came to the conclusion that they were first class in every respect. The tone was similar to that of an ordinary "medium" needle, surface noise was comparatively low, and each needle was found to be good for 15 minutes playing.

(2) *Ordinary Steel needles.*—These are usually divided into four classes: Extra loud, Loud, Medium and Soft. Some makers, Columbia for instance, have their own particular graduations such as "Brilliant," almost a loud tone needle, "Ideal," really a medium tone needle, and "Duragold," a good semi-permanent needle which really ought to have been included in the previous class (No. 1). But the graduation given above gives a broad idea as to what to expect from the representative makes of needles. The various "loud tones" give very similar reproduction, the various makes of "medium tones" are very much alike and so on. The Extra Loud and Loud tone needles are more suited to the playing of dance records where delicacy of rendition is not so important.



FIGS. 3 & 4—Photomicrographs of a Columbia *Brilliant* and an H.M.V. *Loud Tone* needle after one playing.

For orchestral, chamber music, vocal and instrumental records the average person will be much more satisfied with the tonal qualities of the Medium class of needle. Some Soft tone needles are prone to hiss and there is some difficulty in gripping them in the socket. Others while not suffering from these defects give a thin anaemic colour to the tone. However, this question of the choice of grade is a matter for individual taste and so long as users avoid foreign and unknown makes, and use each needle once only they will not go far wrong. Here is a short list of "safe" makes: Parlophone, Songster, Columbia, Chromogram, H.M.V., Pyramid, Edison Bell, Wilson-Peck, Decca.

(3) *Non-Metallic needles.*—Under this heading are the well-known Burmese Colour needles, the more recent Electrocolor and Fayotone needles and, of course, fibres. The latter have been the subject of the most violent controversy that has ever attached itself to the gramophone world. The "fibrists" and "steelites" amongst the gramophone "fans" have fought one another in public and in private for more than a score of years, and still the dispute rages. But fibre users are gradually increasing in numbers. They claim that steel needles give an unnatural metallic tone to all reproduction and simply butcher records. Steel needle users reply that fibre needles are lacking in volume and brilliance while the tone, such as it is, is muddy, the fibre points are constantly breaking

down on heavy recordings and will not in any case respond to a crescendo in the music.

The real answer to both parties is: it depends on the conditions under which each type of needle is used! The needle in a sound-box must be regarded as part of the stylus-bar, and in the design of the sound-box the mass and length of the needle and the flexibility of its point have all to be taken into account. A sound-box which is properly designed for steel needles will certainly give a muddy tone when used with fibres, and the volume will be considerably less. A sound-box which works well with fibre needles will certainly give a brilliant metallic tone with steel needles and may "whistle." It is true that as a rule steel needles will wear records more than fibres and it is also true that fibres used under very adverse conditions will also cause record wear. Wear is caused not so much by friction as by the "reaction effect" or strain between the record and needle when the latter is moved by the groove from side to side. If the sound-box absorbs the strain quickly enough the reaction effect is negligible and little wear results. But if there is this reaction, then a steel needle, being harder than the record material, will break down the walls of the record groove; a fibre needle, on the other hand, will simply have its point knocked off. A sound-box which is really suitable for fibre needles will have little reaction effect *when used with these needles* and the points will rarely break down. Similarly a good "steel box" has little wear on records.

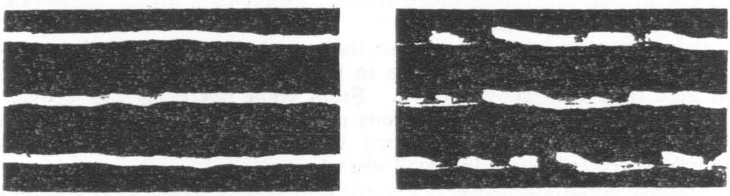
It has been found by experience that even with a sound-box specially made, there are certain conditions in which fibre needles stand up best and give their best reproduction. From what has been said above, it will be realised that these conditions must be equally essential for good reproduction and minimum record wear with steel needles. These conditions are explained in detail elsewhere.

Another important matter is that the fibre needle should have a well-cut point. A shaggy point will give poor reproduction and will soon break down. Use a good cutter such as the Columbia, Alto, E.M.G. It is well to practice a little and examine a few points under a magnifying glass to see which sort of cutting motion gives the best point. Usually a sharp quick movement of the cutter produces a good point. Do not on any account attempt to resharpen the point with the needle in the sound-box. If you do you are sure to buckle the sound-box diaphragm sooner or later.

The best results with fibre needles are obtained on an open or external horn gramophone. The specialists in this type of instrument are E. M. Ginn, 55, Rathbone Place, W.1; E.M.G. Handmade Gramophones Ltd., 11, Grape Street, Shaftesbury Avenue, W.C.2; and W. J. Bond & Sons, Milton Avenue, Harlesden, N.W.10. It is really surprising what volume such an instrument will give with fibres when a suitable sound-box is used. It is almost as great as can be obtained with medium steel needles and the larger instruments will give a volume equal to many electrical gramophones and certainly with excellent fidelity. To get the best results requires a little practice, and then needle point breakdowns are few and far between, and record wear is negligible. The only real trouble is that certain records are apt to get clogged with debris worn off the needle point, but as a rule this only happens if the records are not kept scrupulously clean. Fibre needle points can be rendered less fragile and the tone considerably cleaned up by "doping" or artificially toughening them. There are many kinds of doped needles on the market. Each of the three firms just mentioned produce their own, and in addition there are Astra

Green fibres sold by The Gramophone Exchange, 121, Shaftesbury Avenue, W.C.2.; Wild's Connoisseur fibres made by W. S. Wild, 181, Manor Street, Clapham, S.W.4.; and Meltrope fibres made by Amplifiers Ltd., Billet Works, Billet Road, Walthamstow, E.17. A very successful method of doping fibres is described in the "Miscellaneous Hints" chapter later on in this book.

The other types of non-ferrous needles—Burmese Colour, Electrocolors and Fayotones are much alike both in appearance and in performance. They are of the same shape as an ordinary steel needle but otherwise they resemble fibres in their reproduction characteristics. The best conditions for using fibres are also the best conditions for these needles. Like most other types of needles there are good and bad ones even of the same make, and it is no uncommon experience to be able to play as many as six 12 inch sides without resharpening the point, and yet when another needle from the same packet is tried the point breaks down on the first or second side. Some little controversy still exists on the merits of these needles as compared with fibres. The chief argument put forward in favour of the former, is that they reproduce more detail and give better string and woodwind tone. It is a debatable question. There is no doubt whatsoever that when used under suitable conditions the re-



(*a*) (*b*)

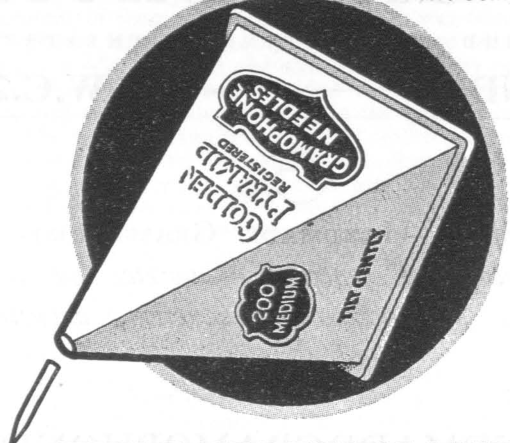
FIG. 5.—Photomicrographs of a new record played: (*a*) 100 consecutive times with non-ferrous needles: (*b*) with medium steel needles.

producing capabilities of the B.C.N. group are first class. A wear test conducted by the Technical staff of *The Gramophone* showed conclusively that record wear was practically non-existent. The test consisted of playing two brand new copies of an H.M.V. red label record 100 consecutive times, each on the same instrument. One record being played with this type of non-ferrous needle and the other with medium steel needles, a special type of electrical pick-up (see Chap. X) being used for the test. Then photomicrographs were taken and these are shewn in Fig. 5 (*a*) and (*b*). As was to be expected the non-ferrous needle produced negligible wear; but the really surprising result of the test was the relatively small amount of wear caused by the steel needles, which of course is an excellent testimony to the conditions in which the tests were made. By viewing the record with the naked eye one could hardly detect the wall breakdowns and reproduction suffered little.

One of the chief factors which retarded the popularity of this type of needle was the absence of a really efficient and quick sharpener. Now, however, there is no excuse. The first really successful device was the Meltrope in which matters were so arranged that the needle and the grinding medium rotate in different directions. This method, first suggested by *The Gramophone,* produces a good conical point and has since been modified rather cleverly in the Fayotone and the Universal sharpeners.

"The finest steel needle I have tried"

Mr. Compton Mackenzie



GOLDEN PYRAMID

GRAMOPHONE

NEEDLES

MAKE your records live. Get the best out of them. Follow Mr. Christopher Stone's example and use "Golden Pyramid–Radiogram" Needles — the needles that give better reproduction.

FOR YOUR RADIOGRAM

use "Golden Pyramid–Radiogram" semi-permanent needles (one tone only). Each needle plays 5 records. Pyramid of 100 needles 1/6.

FOR YOUR GRAMOPHONE

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Chapter V.

POINTS IN GRAMOPHONE DESIGN.

There are many points to be taken into consideration when designing a gramophone and every user should be conversant with at least the more important of them. In the early days it was common practice to make the cabinet, allocate a goodly portion of it to record storage, fit a small horn, any odd tone-arm and sound-box and hey presto ! there was your gramophone. The result was that the record storage was totally inadequate and as a reproducer of music the gramophone was very inefficient. The reliable manufacturers soon realised, however, that if full advantage was to be taken of electrical recording with its extended bass and treble registers, horns of much more generous proportions would be necessary and that alignment errors would have to be very much smaller if record wear was to be kept low, owing to the increased amplitudes which the recording of really low notes necessitated. This alignment question involved due consideration of such things as the " offset " of a tone-arm, " overlap," " needle angle " and " front angle " which were ignored in early instruments. Then someone whispered a mysterious word :—" Exponential " and very quickly the gramophone world went exponentially crazy. Much of the pioneer work on both exponential horns and on gramophone design generally was carried out and expounded in the pages of *The Gramophone* by Mr. P. Wilson, M.A., that journal's Technical Adviser. Later he collaborated with Mr. G. W. Webb, and wrote one of the most comprehensive books—*Modern Gramophones and Electrical Reproducers*—on matters gramophonic that is likely to be published for some time.

Properties of Horns.

There are still some folk who consider that the fuss made about exponential horns has been a mere ramp. Usually, however, it will be found that those people, as well as those who talk the most credulously, have either not the ability or training or have not taken the trouble to understand what the root of the matter is. And in truth it is difficult to obtain a clear and accurate understanding unless one is equipped with a certain knowledge of mathematics. If we attempt here to give a simplified explanation, it is with the full appreciation that many of the more intricate points must be omitted altogether and that even so the explanation may not be easy to follow. First of all, it is necessary to grasp what the function of the horn is. There are a number of ways of expressing this but perhaps the simplest for our present purpose is to say that the horn imposes a load on the diaphragm and thereby enables it to extract energy from the gramophone motor through the record. You can easily appreciate what this means by thinking of a few analogies. One of the best is that of an electric motor. You know that when such a motor is running free, that is without being connected to the machinery or other load in a workshop, very little current is taken from the electric mains. The current increases as the load increases. Similarly, when you connect up a bell-transformer in your house. When no bell-push is pressed there is no load on the transformer and so very little current is taken from your mains : so little in fact that the bell-transformer is permanently connected to the mains without appreciable effect on your electricity bill. Or take what is perhaps the simplest analogy of all, that of pushing a weight along the ground. If the surface is smooth or if the weight is light it requires little work from you to push it; but on a rough surface or with a heavy weight you may have to exert all your energy. The same sort of principle applies in the case of a gramophone sound-box. It takes very little energy to move the diaphragm over a small distance in the open air so that in these conditions the diaphragm passes on very little energy to the air; for remember that when a record is played it is the amount of motion of the needle point that is controlled by the record groove and not the amount of pressure required to move it. In order to increase the energy passed on to the air by the diaphragm we have to put a load on it, that is we have to make the diaphragm more difficult to move; and at the same time we have to arrange matters so that all this extra energy is passed on to the air in the form of sound vibrations and is not merely absorbed in damping material in the sound-box. That is what the horn does: it imposes a load in such a way that greater pressures are required to move the diaphragm over given distances; the air pressure at the outlet of the sound-box is thus much greater when a horn is attached to it than when it is taken away. By the time the pressures have been passed along to the bell of the horn they have become much smaller since the area over which they work has become much larger. From this point of view, then, a horn is also a device for converting a large air-pressure over a small area into a smaller air-pressure over a larger area.

From this explanation of the function of a horn it is clear that there are 3 fundamental requirements of a horn used for the reproduction of sound :—

(1) it must be such that it deals equally well with the varying air-pressures caused by different notes in the scale :
(2) these pressures must be transmitted along the horn in the same sort of way; and
(3) they must be passed on from the mouth of the horn to the outer air in the same proportion.

These requirements determine the shape and size of the horn most suitable for the purpose. It has been shown mathematically and verified rigorously in practice, that to satisfy all three requirements even approximately we require a very long horn with a very big open end and that the shape of the curve of the horn should follow the mathematical curve known as the exponential or logarithmic curve. There is now no manner of doubt about this: any doubt about the performance of particular types of horn only arises because in practice we cannot put a very long straight

FIG. 6.—The Exponential horn as fitted on the Expert Senior gramophone.

horn with a very big opening into a reasonably small space. As we cut the horn short so the loading for bass notes decreases and sound pressure begins to be reflected back from the mouth of the horn instead of being passed on to the outside air. If instead of cutting the horn short we try to economise in space by bending it or folding it back on itself in one way or another we begin to lose the exponential property which is fundamental to the design, and great skill is necessary to keep the deleterious effects to parts of the scale where they will not be noticed so much. The only true exponential horn is a straight horn.

Some Practical Questions about Horns.

A horn may be either circular or rectangular in section and providing the corresponding areas are equal and the section of the latter is not too elongated the aural difference is negligible. There is the probability that the sides of a rectangular horn will vibrate more freely than a circular horn. It is wise therefore to stiffen the sides of a rectangular horn. Even if it were possible to take a straight horn and fold it without distorting the cross section at any point it would be found that the response would be entirely different. The volume would be less and the tone backward due to cross reflections of the sound waves at each successive bend. If any acute bends occurred at large diameters or cross sections of the horn the massacre would be complete. From the foregoing it will be gathered that in designing a horn the fewer bends there are the better the tone will be, and if bends are an absolute necessity it is wise to confine them so far as is possible to the smaller areas of the horn. It is better to confine *acute* bends to that part of the horn where the cross section is not more than 2 inches.

The material used in the construction of a horn should have either a very low or high self resonance, it should be rigid, it should be easy to work, should not buckle easily, and it should be such that the joints can be made firm and air tight. Suitable materials are ebonite, papier maché and terne-plate. Ebonite has the disadvantage that it is brittle, and expensive; papier maché horns have very low resonances but the rigidity of the surfaces is sometimes not very good. Terne-plate is sheet iron one side of which is coated with lead and it has the advantages that it is comparatively inexpensive (a sheet 6 ft. × 3 ft., 22 gauge, costs about 6/–), it is easy to work, is rigid and that a horn made from it usually has low resonances. On no account must a thinner gauge than 22 be used to make a terne-plate horn; 18 gauge would be better.

Opinions on how a horn should be fixed in a cabinet are varied; some prefer to have the horn floating at the mouth and only fixed at the throat, others favour complete rigidity even to the extent of filling the cavities around the horn with absorbent materials or even cement. The purist, however, prefers a rigid mounting. Tables giving the dimensions of horns which will pass notes down to 64, 90 and 128 cycles are given in the *Miscellaneous Hints* chapter on page 60.

Needle-Track Alignment.

When a record is made, the spiral grooves are cut in the revolving wax by a sapphire tool which is stationary and a " carriage " on which the motor and wax are mounted moves in a straight line beneath the tool; so that, in effect, the tool travels from the outside of the disc towards the spindle in the centre. If no sounds are being recorded, the tool cuts a clean spiral in the wax. But as soon as recording begins, the tool waggles a little to and fro along the line, with the result that a wavy groove is cut instead of a spiral. The point to notice is that the tool is always moving to and fro in a line which passes through the centre of the disc.

When you play a record, the needle point should move to and fro in the same way. With ordinary sound-boxes it can only move in a direction perpendicular to the face of the sound-box, since the knife-edges or pivots or whatever they are that the stylus-bar rocks on, are in a line with the face of the sound-box. So in a gramophone with perfect alignment the line joining the centre of the record to the needle point should always be at right angles to the face of the sound-box. You can test alignment accurately by means of a Wilson Protractor, or roughly by placing a sheet of notepaper with one of its corners at the needle point and one edge passing through the centre of the turntable spindle. The sound-box looked at edgewise should then lie in the direction of the other edge. Try it, with the needle resting at different points of a record. (Don't set the turntable moving of course). You will find that only at one, or at the most two, positions will the face of the sound-box be exactly in the direction of the other edge. The reason is that the sound-box moves across the record in a curve and not in a straight line. It can be shown that the difference between the curve and the straight does not matter in the least so far as the music is concerned. But it does matter in this question of alignment.

In the Balmain gramophone, the sound-box, horn and all float across the record and the needle does actually move in a straight line, so that if the sound-box is set accurately at right angles to that straight line, the alignment is correct everywhere across the record. That is impossible with a swinging tone-arm, but it is possible to arrange that the alignment shall not be more than 2 degrees in error at any point of a 12 inch record. This is done by making the needle come a certain distance in front of the turntable spindle and at the same time making the face of the sound-box point in a direction which is well to the right of the pivot at the back about which the tone-arm swings across the record. The exact distance by which the needle should overlap the spindle centre depends on the length and offset of the tone-arm or pick-up arm. The correct amounts of overlap are given in the table on page 61. Don't run away with the idea that correct alignment is a universal panacea for all your gramophone troubles. But clearly it is of importance that the needle should always rest evenly and symmetrically in the groove and not overhang the top of one wall and dig its point into the other. And it is this that good alignment ensures.

The Tone-arm.

This important component is really part of the horn and strictly speaking should have a similar rate of taper as the horn for which it is intended, though a few inches of parallel bore at the sound-box end is often an advantage. With the larger horns the parallel bore has the effect of cleaning up the bass register. A properly designed tone-arm should be of good length (certainly not less than 8 inches), it should have as few acute bends as possible, and the forward joint should be designed so that the axis through it is as nearly at right angles to face of the sound-box, when in position, as is possible. With some of the S shape tone-arms where the axis of the rise-and-fall hinge is nearly at right angles to the sound-box bore the needle does not enter the groove perpendicularly and symmetrically, and the length of the needle governs the angle the sound-box face makes with the record. This angle should always be 90 degrees and clearly this cannot be obtained with needles of different lengths unless the rise and fall axis is parallel to the sound-box bore.

Both the rear and forward joints of a tone-arm should be as frictionless and as free from rattle as is possible and they should be absolutely air-tight. A reasonable amount of " offset " should also be provided for.

Offset, Overlap, Needle Angle.—Many folks are puzzled by these terms. What are they, what do they mean? Full explanations are given later, but perhaps the answers are shown clearly enough in Figs. 7 & 8. The ideal offset is 3¾ inches, though few commercial tone-arms have an offset of more than 3 inches. The length, the offset and the overlap have all to be taken into account when setting up a tone-arm or repositioning a motor so that the alignment errors may be as small as possible. If the offset of a tone-arm is less than 2 inches then no matter what the distance

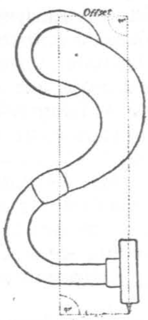

FIG. 7.—Offset Diagram.

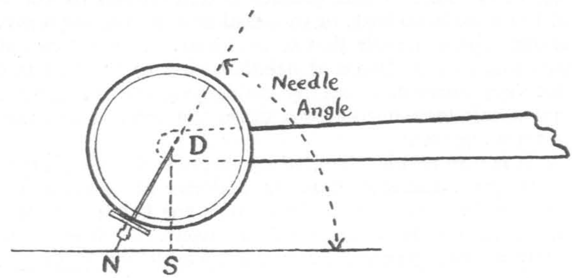

FIG. 8.—Needle Angle and Overlap Diagram.

between the tone-arm centres is, or the amount of overlap provided, alignment errors, and consequently record wear, will be excessive. There is still one other factor, that of " needle angle," which enters into this question of alignment. Needle angle is the angle which the needle makes with the face of the record looking at the sound-box full face. The illustration Fig. 8 will clear any doubts as to what is meant. It has always been a controversial question amongst the experts regarding the best angle. Some say that an angle of 50 degrees reduces surface noise and minimises needle hiss. This may be so, but experiment shows that this is always at the expense of some detail in the music. The best compromise is an angle of about 60 degrees, though a little divergence either side of this—57½ or 62½—makes little or no difference. It will be seen on referring again to Fig. 8 that this angle is inter-related with the overlap. Assuming that S is the centre of the turn-table spindle, then the distance NS is the overlap and this distance is always measured from the centre of the turn-table spindle. The amount of overlap to allow when setting up a tone-arm or a motor depends on the distance between the centre of the tone-arm back pivot and the needle point and the amount of offset. The table on page 61 gives the best overlap distances for various lengths of tone-arm and offsets. Notice that where the offset is 2 inches there should be no overlap. When the offset is below 2 inches the best conditions for track alignment are obtained when the needle point *falls short* of the turntable centre. But an arrangement of this sort is undesirable for other reasons into which we cannot enter here.

THE SOUND-BOX.

A gramophone sound-box is seemingly quite a simple affair ; a moving finger or stylus-bar pivoted in some way so as to transmit vibrations picked up from the record by the needle to a diaphragm, and a casing for the diaphragm containing an air chamber whose outlet to the tone-arm is smaller than the diaphragm itself. That is all. Actually, however, the sound-box is a delicate piece of mechanism which includes infinite possibilities of variation. It is only in recent years that the precise mechanical function of each of the component parts has become clear. It is not the purpose of this little book to enter into long theoretical explanations. Potential students should read " Modern Gramophones and Electrical Reproducers," price 10/6, published by Cassells. But it should be emphasised that the sound-box is, or should be, a balanced instrument in which the various parts have all been designed to work together. Part of this balance is determined by the weight and stiffness of the needle, so that, in the ideal at any rate, for a given sound-box there is one type of needle that suits it best. In practice a little latitude is permissible in the choice of needle owing to the fact that the human ear is not very sensitive ; but by taking extremes in needles, *e.g.*, a Tungstyle and a soft-tone needle or a fibre, the general truth of the proposition is at once apparent.

It is impossible, then, to say in general which is the best type of needle apart from the goodness or badness of manufacture. Similarly it is impossible to say definitely what is the best material or shape or size for the various parts of the sound-box itself. All these things are inter-related. Certain broad principles have been established, but in practice compromises have to be made.

Beginners often ask whether they could improve their sound-boxes by having this, that or the other diaphragm fitted. This question is one which cannot really be answered by a plain " yes " or " no." Theoretically the best type of diaphragm is one which has small mass (weight) and great stiffness. Few of the composite paper or fibrous diaphragms satisfy this condition ; mica does to a notable extent, and so do thin glass and some of the corrugated aluminium diaphragms. But it may happen in any particular sound-box that faults in other parts may be mitigated or masked by counterbalancing faults in the diaphragm. A sound-box *may* therefore in practice be improved by inserting a diaphragm which is faulty in place of a more theoretically satisfactory one. The best sound-box will naturally be one in which each part is as nearly perfect as it can be made ; probably that is only achieved in individual sound-boxes made and tuned like a delicate scientific instrument. In mass-production the aims must be to produce sound-boxes of high standard consistently. In this, as in other things, the best may be the enemy of the good. Standardisation in mass-production so as to produce consistently good sound-boxes is a difficult matter which only a few makers have overcome.

Front Angle of Sound-box.—When a sound-box is in the playing position on the record and is looked at edgewise it should be exactly at right angles to the record (see Fig. 9). This is very important. In the Tone-arm notes on page 21 it was stated that the axis through the forward joint should be parallel to the bore of the sound-box when in position. Very few tone-arms comply with this specific ruling. As the sound-box is moved up and down, therefore, it begins to tilt over slightly ; it doesn't go up parallel to itself. And when the sound-box is on the record, unless the height of the tone-arm is exactly right, the sound-box may be out of the vertical, with the needle leaning slightly over one wall of the groove and digging its point into the other wall. The remedy in this case is simple. Cardboard or rubber washers (with the centre hole of appropriate size) should be inserted between the tone-arm and baseboard so as to raise the tone-arm sufficiently to let the sound-box come into a vertical position on the record. This remedy applies in the more usual case when the sound-box originally tilts over to the left of the vertical. In the other event, a rubber mat can be placed on the turntable in order to raise the sound-box. A turntable mat, by the way, will minimise any tendency for the record to slip. If the thickness of the mat is insufficient to raise the sound-box the required amount, the tone-arm can be lowered a little by letting the tone-arm base into a circular rebate on the mounting board. The trouble in these cases is that the fixing is only right for one size of sound-box or length of needle. So it is best to set it for the sound-box and needle you use with the heaviest recordings where it matters most. With light recordings a slight error does not much matter.

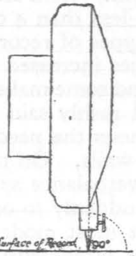

FIG. 9.—Front Angle Diagram.

It was mentioned in the notes on needles that a sound-box which is primarily designed for steel needles is unsuitable for use with non-ferrous needles. The reason is that the needle is really part of the sound-box and the difference in mass and material for given masses of the other components which constitute a sound-box have a decided effect on the tone. The best results are obtained when all the parts are carefully chosen by experiment so that they are in " tune." Unfortunately this business of tuning a sound-box is too expensive a proposition for the majority of manufacturers, as each box after assembly may need careful and minute adjustments probably entailing hours of patient work. Only the " hand-made " specialists, to whom quality, not quantity, is of vital importance, can afford to undertake the tuning and making of special sound-boxes for non-metallic needles. It should be mentioned, however, that some mass-produced sound-boxes have been produced, after careful study of the requirements and by installing special machinery, and thus a standard has been achieved which falls very little short of the hand-made sound-box in efficiency. The majority of modern sound-boxes are quite incapable of being tuned owing to their particular forms of construction. The most that can be done is to carefully adjust the end pivots of the stylus mounting, or to reduce the mass of the nut and screw which is usually employed to make the joint between the centre of the diaphragm and the stylus-bar end or to vary the pressure of the gaskets. Mention of gaskets brings us to a common failing in a good many sound-boxes, namely the hardness of the rubber used. We all know that rubber perishes with age and many sound-boxes that function well when they leave the works deteriorate in a short space of time. The rubber hardens, losing its resilience and then fails to damp out the diaphragm resonances as they radiate from the centre. The result is that the tone becomes coarse and uneven, and eventually a whistle accompanies practically every soprano and string record.

EFFECT OF WEIGHT ON THE RECORD.

There is little doubt that a nice adjustment of the pressure between the needle and record can effect a decided improvement on the reproduction.

But unfortunately there is no hard and fast rule for determining what the pressure should be for best results; it depends on so many things, such as type of sound-box, and even upon type of tone-arm. With steel needles the actual weight on the *needle point* must not be less than 4 oz. nor more than 6 ozs. A satisfactory compromise for all types of records is $4\frac{1}{2}$ oz. With non-metallic needles, this can be sometimes increased to advantage to as much as 7 oz. or $7\frac{1}{2}$ oz. with fibre needles, and some makers use even 8 to $8\frac{1}{2}$ ozs. Despite what has sometimes been rashly said in the gramophone and wireless press, too light a weight causes the needle to chatter in the groove and to ride up and down on the walls. On the other hand too heavy a weight may cause the needle to overbalance as it were, whenever the groove moves the point sharply and suddenly to one side or the other. Weight adjusters are obtainable to fit most modern tone-arms and one particular tone-arm—The Crescent—is fitted with a weight adjusting device. Incidentally this is one of the few modern tone-arms in which there is no forward joint and consequently part of the weight of the tone-arm is added to that of the sound-box so that it is just possible that with some sound-boxes the weight on the needle point will be excessive for steel needles. Nevertheless it is one of the best commercial tone-arms. The best advice, regarding the correct weight on the needle point, is to try for yourself and when you have got a weight that suits your own particular conditions let well alone. A device which can easily be made at home, for measuring the weight on the needle point is described on page 62.

MOTORS.

Spring Motors.—For good gramophone reproduction a first class motor is essential; and it must be kept in first class condition. Otherwise the speed of the record will fluctuate and the pitch and quality of the music will waver in a distressing manner. However efficient the rest of a gramophone is, an unsteady motor will cause a piano record to whine and be metallic, much as though it were a Hawaian Guitar. So, too, a soprano voice will wobble and even blast. All this is bad for the ear and for the record as well.

The essentials of a good motor are (in order of importance):—

(1) It should run steadily and have a good reserve of power, so that it can supply the necessary energy for a sudden heavy note or a long sustained note without altering speed. Try a piano record such as *Rachmaninoff's Prelude* played by *William Murdoch* (Columbia DX 244) and see whether the chords are well sustained without fluctuation of pitch and power. Try also a soprano or fiddle record with a long drawn out note. See that the record is centrally placed on the turntable. A "swinger" (see page 38) can give a wobble in pitch whether the motor is steady or not.

(2) It should run fairly silently. A slight *continuous* noise does not matter very much; it will probably disappear as soon as a record is being played and the motor has some work to do. But an *intermittent noise*—crr, crr, crr—each revolution is a sure sign that the governor is not working properly and the motor should be overhauled by a competent mechanic at once.

(3) The turntable should run true. This is a counsel of perfection, and very few motors have perfectly true turntables. But there

is no reason why the up-and-down motion should be more than just perceptible. The turntable should fit tightly on the spindle. Press gently with the fingers on the outside rim and see whether you can rock the turntable on the spindle. If you can, the motor is not satisfactory.

(4) The winding gear should not be noisy. This does not affect the running of the motor, but unnecessary mechanical noise is annoying to say the least.

Apart from the so-called " hunting " noise referred to at (2) above, there is another noise for which you should look out. A rather loud bumping noise comes to all spring motors sooner or later and this means that the spring drums want cleaning and packing with new grease. If this is not attended to immediately a new spring will be required before long.

Electric Motors.—Great strides towards perfection have been made with this type of motor during the past year or two. Previously efficient ones were few and far between and expensive at that. Now, however, a good electric motor costs little more than a large spring motor and in some instances it is even cheaper.

The principal types are the Universal Commutator type, the Induction type and the Synchronous type.

The Universal Commutator type is suitable for operation either on Direct Current or Alternating Current supplies. Although such motors usually have good pulling powers and uniform speed, manufacturers have had difficulty in making them efficient in other respects. For instance many samples are miniature broadcasting stations, in that the commutator and brushes generate high frequency sparks which are radiated into the ether and are picked up by the aerials in the vicinity, amplified in neighbours' radio sets and reproduced through speakers at an alarming strength, sometimes being loud enough to completely spoil the reception of radio programmes. The saddest part about all this is that unless he owns a radio receiver the owner of the motor does not realise what a source of annoyance his gramophone is. Interference of this kind is known as radio frequency interference. Other universal motors, even if they do not suffer from this defect, cause what is known as electrostatic interference, but this only affects users of electrical reproducers where a pick-up is used. (*See* Buying a Radio-Gramophone, page 43).

Two firms of repute after submitting a universal motor to *The Gramophone* for review, decided, on receiving that journal's report, to withdraw the motor from the market, notwithstanding the fact that large quantities were in production. In both cases the reason was the large amount of radio frequency interference.

Universal motors that can be recommended are the B.T.H. Standard model which costs 6 gns., and the more expensive French " Era " which costs £10.

The Induction type of gramophone motor is only suitable for use where Alternating Current is available, and it is with this type that the greatest improvements have been made. In the early models there seemed to be some difficulty in obtaining good pulling power and uniform speed without an excessive rise in temperature. But in modern induction motors this has been successfully overcome, notably in the Collaro, the Garrard, the H.M.V. and the G.E.C. models. Moreover none of these suffer from radio-frequency, electrostatic or audio frequency (hum) disturbances. The Collaro (" Empire " model) is worthy of special mention since its all-round efficiency is high and its price is inversely low. It costs £3. The Garrard and G.E.C. models are equally efficient but cost £4 19s. 6d. and £4 15s. od. respectively. They have advantages in that the depth required beneath the motor board is less. The H.M.V. motor is, of course, incorporated in all their electrical reproducers, and may be purchased separately for £6.

About the Synchronous motor very little can be said at the moment. Although one or two are already on the market, there seems to be some doubt as to their pulling powers and on these no suitable method of starting has been evolved. For it must be noted that the speed of a synchronous motor is governed entirely by the frequency of the mains supply (there is no mechanical governor—a great boon). The motor has to be started by a flick of the turntable before being switched on and until one has learned the knack of imparting just the right strength to set the turntable revolving there is always a possibility of the motor synchronising at half the required speed. The B.T.H. people have, it is understood, devised a starting switch whereby this is impossible. The advantage of these synchronous motors is that the turntable speed cannot be varied in the same way that it can in mechanically governed motors. As the frequency of A.C. mains are constant enough to warrant the manufacture and sale of electrically driven clocks, we may be satisfied that the speed of the synchronous motor will be sufficiently uniform for the playing of gramophone records.

Automatic Stops.

The majority of gramophones and gramophone motors are fitted with an automatic stop and on the electric motor this is combined with an automatic switch for cutting off the current. Auto-stops are an advantage when you want to put a record on and not to have to bother about being at hand at the end of it. Although in recent years they have steadily improved in design there are still some which only function sporadically, and false security is infinitely worse than insecurity. The commonest defect of auto-stops is that they stop the turntable too suddenly thereby tending to strain the delicate governor springs of the motor. With the synchronous electric motor, of course this criticism does not apply. It is a fact that the "fans" of the gramophone world invariably remove the stops from their new gramophones and that electric motor users seldom stop the motor to change the records. Nearly all records have a "run-out" groove, *i.e.*, a track which gently leads the needle to a blank groove where it can play idly until some one stops it or until the motor runs down.

Automatic Record Changing.

There seems to be little hope of a successful record changing device being produced for use with the acoustic gramophone. The only one of any note was produced in 1927 by the Gramophone Co. Ltd., and incorporated in the H.M.V. Automatic gramophone.

For the electrical "fan" however, there are already a number of instruments which incorporate record changing units, notably the H.M.V. 531 and 522, the Columbia 604 and the Marconiphone Radio-Autogram. All these are radio-gramophones. In addition to these there is the H.M.V. 553 electric gramophone and the H.M.V. No. 117 playing desk. Each of these is capable of playing eight sides consecutively or repeating any one side eight or a lesser number of times. But there is no automatic unit

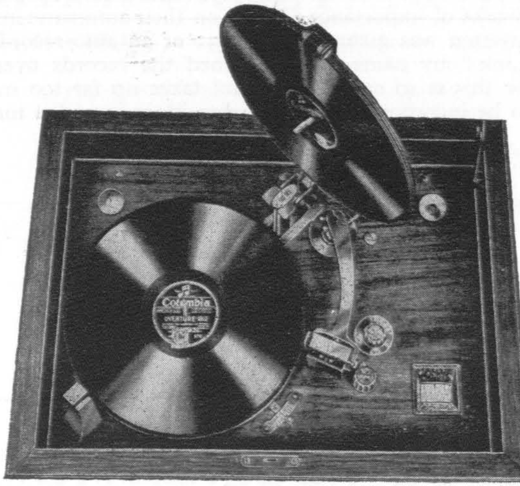

FIG. 10.—The Columbia Automatic Record Changing Unit.

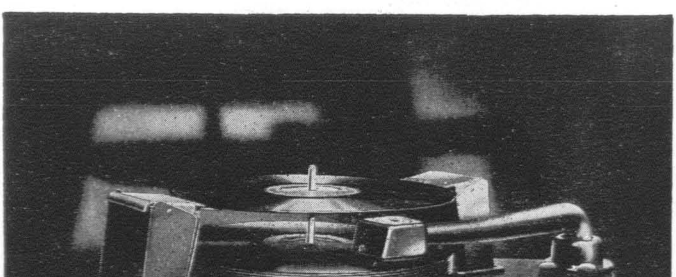

FIG. 11.—The H.M.V. Automatic Record Changing Unit.

on the market at present that turns the records over so that large musical works can be played in unbroken sequence. The Gramophone Co. have overcome this difficulty to some extent by producing special coupling records of the major works of importance for use on their automatic instruments.

A demonstration was given late in 1931 of an auto-record changing unit—the "Link" by name—which turned the records over, but the mechanism for this is so complicated and takes up far too much space to enable it to be incorporated on any instrument intended for domestic use.

CHAPTER VI.

OVERHAULING A GRAMOPHONE.

Although the complete overhauling of a gramophone including the fitting of new springs to the motor and the re-adjustment of the sound-box, is not a job which the ordinary layman can tackle with full confidence, quite a respectable improvement can be made in the general performance of the instrument by a series of systematic and simple adjustments. Suppose your gramophone has, through want of a little thought and care, developed a series of complaints. The sound-box has begun to buzz on loud orchestral passages, or on soprano voices, or on the trumpet solos in a dance band record; new records after being played half a dozen times show signs of wear—grey lines and the like—and the motor has developed an irregularity in speed which makes all records, especially the piano solos sound "catty" and the irregularity is accompanied at intervals by a curious bump, bump, bump. How would you start to cure these ills? If you are not mechanically minded and prefer not to experiment with things you do not understand you will place the instrument in the hands of a reliable gramophone engineer. And you will be very wise. But make sure that the man knows his job. If, on the other hand, you prefer to find things out for yourself and have a little mechanical knowledge then the following notes will be of some assistance. One golden rule to start with—be methodical, tackle each job separately and for each component you attempt to overhaul provide a small empty box in which to put the various parts. Then there will be little risk of losing or mixing the screws, nuts, ball-bearings, gear wheels etc.

Motor Troubles.—It is better to tackle the motor troubles first because it is practically impossible to judge the performance of any sound-box if the motor is not behaving in a respectable way. If it is not pulling properly the first sign will be that the pitch of some notes vary. As the speed of the motor reduces so the pitch will lower; if on the other hand the motor suddenly decides to run faster, then the pitch will be raised. The next irregularity noticed is the intermittent bump. This is where our operations begin. The bumping can be due to either a lack of or to hardened grease in the springs drums or it is possibly being caused by one of the teeth on the governor spindle worm of or on the worm-wheel on the turntable spindle, becoming burred. A piece of grit or any foreign body embedded in the teeth of these gears will also cause trouble. There is also one other possible cause of irregular speed and excessive mechanical noise though fortunately it is a rare occurance with the modern gramophone motor. On some motors the worm wheel is made of a hard fibre composition which is faced on both sides by thin metal discs. These are rivetted on before the teeth are cut and when the teeth are eventually milled out these discs form part of the wheel. If at any time the rivets work loose, the teeth in the discs do not engage with the worm at precisely the same time as the teeth in the fibre portion.

It will, of course, be necessary to remove the motor from the cabinet and motor board and please don't forget to *allow the motor to run down* and then to *remove the winding handle.* Many amateur and even skilled mechanics forget these essential points. If you forget the former then when the time comes for removing the governor you will probably suffer severe personal injuries. If you forget the latter—well it will be checkmate. Having attended to these little details, first take out the governor spindle by removing the end bearings, which, for the time being must be placed in a small tin or an old basin containing clean petrol or paraffin. Wash the spindle thoroughly, not forgetting the face of the speed regulator plate, and then very carefully examine the worm. If there are any burrs, however slight, on any of the threads they must be filed off with a small half-round *smooth* file; then polished a little with fine emery paper. The worm-wheel on the turntable spindle must be examined and the teeth treated in the same way if necessary. If it happens to be one of the fibre composition type with end plates rivetted on make sure that there is no looseness between the fibre portion and the metal plates. If, after giving the rivets a tap or two with a hammer and a flat nose punch you have any doubts about looseness, then it is better to have a new wheel fitted by the makers. The remaining gears should be examined and burrs removed, but if the teeth are badly worn, especially those on the small pinion on the bottom of the turntable spindle, the wheel should be replaced by a new one; or in the case of the spindle pinion a new complete spindle will be necessary as the pinion is usually milled out of the spindle itself. If new parts are required it is better to return the motor to the makers or place it in experienced hands. Messrs. Edison Bell Ltd., have a special repair workshop and will usually undertake most motor replacements and repairs.

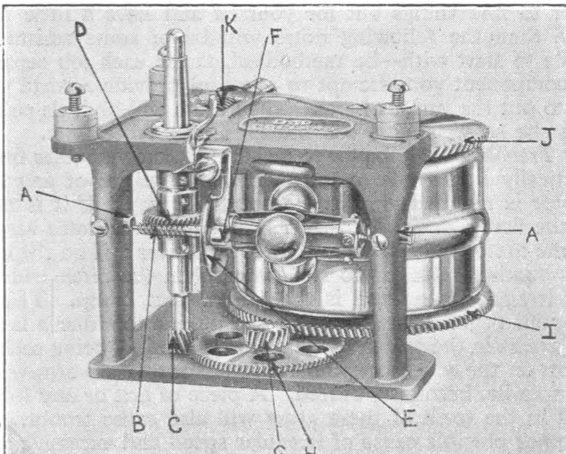

FIG. 12.—The Collaro D.30 Double Spring Motor. A, End Bearings; B, Governor Spindle Worm; C, Turntable Spindle Pinion; D, Turntable Spindle Worm Wheels; E, Governor Plate; F, Governor Pad; G, Intermediate Pinion; H, Intermediate Wheel; I, Driving Wheel; J, Winder Gear; K, Winder Worm.

The motors illustrated in Figs. 12 and 13 are of two different types. That in Fig. 12 is a Collaro type D. 30, and Fig. 13 is an H.M.V. four spring type. Reference to the captions will clear up any doubts as regards the positions of the gears, governor pads and end bearings on each motor. The principal difference between the two is that the turntable on the H.M.V. motor is directly driven by a worm wheel which is in gear with a worm on the spring drums, whereas the Collaro turntable is driven through intermediate gears between the drums and turntable spindle.

Notice that, in effect, the pinion C in Fig. 12 corresponds to the worm G in Fig. 13.

Now turn your attention to the governor pad. If this is hard and dry, the irregular speed may be due to this fact alone. If so, it can be overcome either by fitting a new pad or by softening the old one by soaking it in thin oil, such as Wakefield "Oilit," for a time and then washing in clean paraffin. The most expedient method is to fit a new one. How to find the correct position of the pad when replaced will be described later.

The next operation, that of cleaning and repacking the spring drums with new grease, is perhaps the most difficult to undertake by an amateur and is best left to a reputable gramophone repairer. Some slipshod mechanics will not tackle the job properly and it is essential that you should know of the whole operation so that you can see that it is carried out to the full.

The spring drums should be removed, opened and the springs taken out and soaked in paraffin. The springs must be washed, also in paraffin, inch by inch on both sides and dried. The drums must be treated likewise, the springs replaced, packed with good quality grease and the drums fastened. The slip-shod repairer will not take the trouble to do this; all he does is to open the drums, soak them in paraffin *without removing the springs* and then refill the drums with new grease. It is most important that all the old congealed grease be removed from the springs; if this is not done then the springs become oxydised and, in time, break; and it is also important that the paraffin should be dried off. This operation, so far, may seem delightfully simple and straightforward, but assuming that you managed to take out the springs without receiving a black eye, and have cleaned both springs and drums thoroughly, you may have to give up the task of replacing the springs in disgust. It is a job that only becomes easy once the knack of doing it is learned—much in the same way as obtaining that final gloss when french polishing. That is one reason why the overhaul of the drums is best left to those experienced in handling them.

The ratchet and pawl on the winding gear should next receive a little attention, though it is unlikely that this part of the mechanism will require anything more serious than a good clean up and lubrication. The worm on the winding shaft will need to be washed and examined for burrs, and if necessary treated in the same way as the other gears mentioned previously.

Reassembling.—There is nothing in the reassembly which calls for any special mention, apart from the oiling of all bearings and frictional contacts, until it is time for the governor spindle to be replaced. Here a little extra care is necessary in order to get the teeth of the governor worm meshing properly with the wheel on the turntable spindle. Practically the whole of these adjustments depend upon the correct aligning of the spindle in the end bearings. Notice that the holes in these are eccentrically located. The governor spindle must be placed in position between the bearings and these patiently adjusted so that there is just a little freedom between them when the spindle is moved backwards and forwards. There must also be a small amount of freedom —or backlash—between the worm and worm-wheel when the spindle is twisted slightly. This is to ensure that the teeth are not too deeply in mesh, otherwise the movement would be sluggish. On the other hand, if too much play is allowed the motor may become noisy. For these reasons it is sometimes a temptation to make the adjustments with the motor running. But *do not do it.* It is asking for a nasty mess; for if the governor worm comes out of gear the springs will take charge in a startling fashion and you may find yourself with bleeding fingers and the gears on the motor ruined.

Having patiently adjusted the end bearings to your liking, the next operation is the refixing of the governor pad. The most important point here is to allow this to project from the clip by the correct amount so that when the speed regulator on the motor board is set to 78 the turntable is running at 78 revolutions per minute. One method of ensuring this is to set the regulator pointer at 78 and place a stroboscopic speed tester (see page 64) on the revolving turntable. This tester can only be used by those who have alternating current laid cn. The governor pad must be adjusted until the pressure on the governor disc is such that the stroboscopic spokes appear to be stationary when the turntable is illuminated by electric light and with the regulator pointing to 78. For those who have gas or D.C. lighting the best method is to use one of the mechanical speed testers, like the Columbia and H.M.V. models, and adjust the governor pad until the correct pressure is found. It should be noted however that on some motors an eccentric cam arrangement is provided so that the setting of the regulator can be adjusted independently of the governor pad.

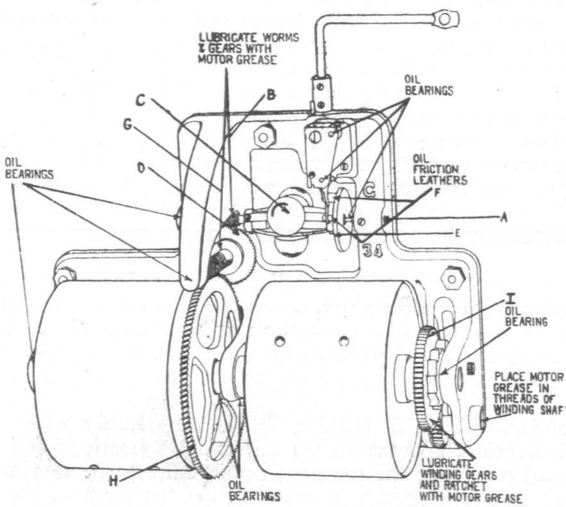

FIG. 13.—The H.M.V. Spring Motor.
A, End Bearing; B, Governor Spindle Worm; C, Governor; D, Turntable Spindle Worm Wheel; E, Governor Plate; F, Governor Pads; G, Turntable Spindle Worm; H, Driving Wheel; I, Winder Gear.

Having settled this little problem, the teeth of the governor and winder worms, the worm wheels and other gears must be smeared with motor grease, a little machine oil dropped on the governor pad and every bearing re-oiled with light oil. The turntable should then be placed in position and the motor wound up and run down several times. It will probably be necessary to make slight readjustments to the end-bearings and governor pad until everything runs silently and smoothly.

Insulation.—Finally comes the remounting of the motor on to the motor board. However silent the motor may be when held in the hand, you will find that unless a little care is exercised when refixing it on the board it seemingly develops mechanical noises. The only way to overcome this is to insulate the motor completely from the motor board. On most gramophones the motor is partly insulated by thick rubber washers placed between the board and the motor frame. This, in many cases, is not sufficient. Mechanical noise can be considerably reduced by inserting rubber washers between the heads of the fixing screws, and the board or plate (if the motor is mounted on a metal plate) and also by covering the screws themselves with rubber sleeving. Some " fans " even fasten strips of rubber round the edges of the motor board, so that the board itself rests on rubber. These extra precautions are well worth while. The tightening up of the motor fixing screws should be done gradually so that the turntable when revolving is as nearly parallel to the motor board as is possible. If the turntable does not run true, to test see if it fits on the spindle nose snugly by pressing lightly on the outside edges. If it rocks a considerable amount there is no remedy which the ordinary layman can apply without returning it to the maker or sending it to the motor mechanic. But if there is only a little " play " the turntable can be " ground on " by rotating backwards and forwards on the stationary spindle to which a small amount of fine carborundum paste and thin oil (Wakefield " Oilit " is excellent) has been smeared. Grinding paste can be obtained from most garages where it is used for grinding the valves of motor cars. This operation will necessitate the dismantling of the turntable spindle again, as otherwise there is the danger of spraining the delicate governor springs. Some turntable spindles are fitted with a cotter pin which engages in a slot in the turntable " boss " when in position. Others rely entirely on frictional contact between the tapered faces for the drive. With cottered spindles the cotter will have to be removed, either with pliers or knocked out with a small flat nose punch and hammer before the grinding operation can be attempted. If you find it necessary to resort to the hammer and punch make quite sure that the cotter is not screwed in and be very careful to support the spindle on both sides of the cotter, otherwise you run the risk of bending the spindle end. Be careful, also, not to bruise the spindle in any way. When the turntable fits the spindle to your satisfaction there should be no wobble however slight. Wash the spindle and turntable boss thoroughly with paraffin and remount the spindle and motor as previously indicated.

If the turntable itself is warped and consequently does not run true, then there is no remedy which an amateur can apply to correct it. Indeed, manufacturers have difficulty in producing turntables that remain absolutely true. In many cases they are true when they leave the factory, but they warp after being in use for some time.

These irregularities and possible remedies are by no means the be-all and end-all of the motor troubles, but they are—apart from spring troubles—the only ones that the average man can undertake with any assurance of success, that is, of course, assuming that he possesses an elementary knowledge of mechanisms.

The Tone-arm and Record Wear.—One of the causes of premature record wear can sometimes be traced to the lateral movement of the tone-arm. Anything which tends to create side-pressure (see page 10) by impeding the movement of the arm across the record, such as a poorly designed automatic stop, or a stiff back joint, must be avoided at all costs. Here a word of warning is necessary; a very loose back joint will also cause side-pressure and premature record wear. It is quite a simple matter to overhaul the back joint. The tone-arm must be taken off the back board and the small grub screw, to be found in the base casting, removed. It should then be possible to withdraw the ball race. (Take care not to lose any of the balls). Wash these, the whole of the base and body of the tone-arm in clean paraffin and allow to dry thoroughly. Then, if possible force a little motor grease into the forward joint of the tone-arm and add a few drops of thin oil. The air tightness of the tone-arm joints is most easily tested by closing up the base of the tone-arm with the palm of your hand and then blowing tobacco smoke down from the sound-box end of the arm. There should be no leakage of smoke through the joints. Next apply a liberal amount of motor grease to the race and set the balls up in the grease. This will hold them in position until the race has been replaced and the grub screw screwed home. A small quantity of oil can be applied with advantage. The tone-arm is now ready for replacing, and when this is being done particular care must be taken to get the joint between the horn and the tone-arm absolutely airtight by smearing this also with grease. With the automatic break still disconnected and sound-box folded back it should be possible to blow the tone-arm across the turntable. With a tone-arm of the "Crescent" pattern where there is no forward joint it is impossible to blow it across the record. The reason is obvious: the end of the tone-arm is only supported when the needle is on the record. However, whether it is possible or not to blow your particular tone-arm across the record, this criterion must be accepted as an indication of the freedom required before the adjustments to the back joint are considered satisfactory.

Sound-boxes.—One of the most frequent complaints about sound-boxes is that of buzzing or chattering in the loud passages of a record. This can be caused by (1) a cracked diaphragm, (2) a "tired" or kinked aluminium diaphragm, (3) a loose joint between the stylus bar and diaphragm, (4) the breaking away of the wax usually found on this joint, (5) loose or too tightly adjusted end pivots in the case of pivoted stylus bars, (6) perished or hard rubber gaskets, and (7) the bad fitting of the sound-box on the tone-arm.

(1) The only remedy for a cracked mica diaphragm is a new one. When fixing this to the stylus bar it is of the utmost importance to see that the face of the stylus bar end is parallel to the face of the diaphragm when mounted between the gaskets. Otherwise the mica will crack. The nut which holds the diaphragm in position on the stylus bar must screw into the flat of the stylus squarely and should have as little mass (weight) as possible; excessive mass here will have the effect of making the reproduction coarse and uneven. The nut must be screwed up until the diaphragm is firmly held and a

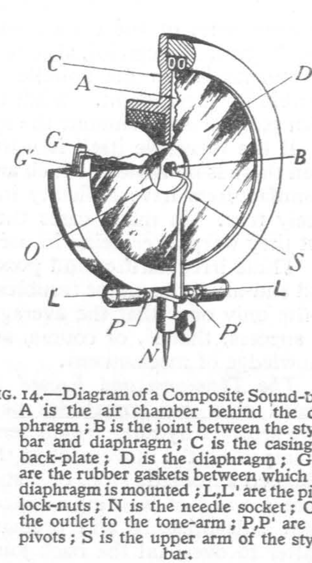

FIG. 14.—Diagram of a Composite Sound-box. A is the air chamber behind the diaphragm; B is the joint between the stylus bar and diaphragm; C is the casing or back-plate; D is the diaphragm; G,G' are the rubber gaskets between which the diaphragm is mounted; L,L' are the pivot lock-nuts; N is the needle socket; O is the outlet to the tone-arm; P,P' are the pivots; S is the upper arm of the stylus bar.

little wax compound consisting of two parts, by weight, of beeswax and one part resin dropped on the joint. Alternatively put a piece of the compound about the size of a pin's head on the nut and touch it with a hot bradawl or long nail so that it melts and runs around the joint. Turn the box over and treat the other side of the joint in a similar manner. When placing the diaphragm into the sound-box body, care must be exercised to ensure that no part of the periphery of the diaphragm touches the shell of the sound-box. If it does not clear all the way round, it is more than likely that the sound-box will buzz. If it does not do so at first, it will as the gaskets get older.

(2) As with a cracked mica, the only sure cure for a "tired" aluminium diaphragm is a new one. If the joint between the stylus bar and diaphragm is by means of a small nut and screw, as in the Limit sound-box, then the remarks about replacement mentioned in connection with mica diaphragms apply in this case. If, however, the diaphragm is fixed to the stylus by means of a rivet, as in the Meltrope sound-boxes, a new stylus bar with diaphragm already mounted must be obtained from the makers. The joint must be examined minutely to make sure that there can be no possible rattle. Both sides of the joint must be treated with wax as in No. 1.

(3) The remedy for this is obvious. The nut or rivet, whichever it may be, must be carefully tightened and waxed.

(4) The cracking or breaking away of the wax round the stylus and diaphragm joint is one of the most common causes of blasting and buzzing. Very often a sound-box can be cured of this distressing complaint by holding it, aperture downwards, about six inches above a lighted match until the wax begins to soften—it must not be melted. More obstinate sound-boxes will need new wax entirely, and in that case it is safer and more expedient in the long run to remove the diaphragm from the box, clean off the old wax from both sides and remount again in the manner described earlier.

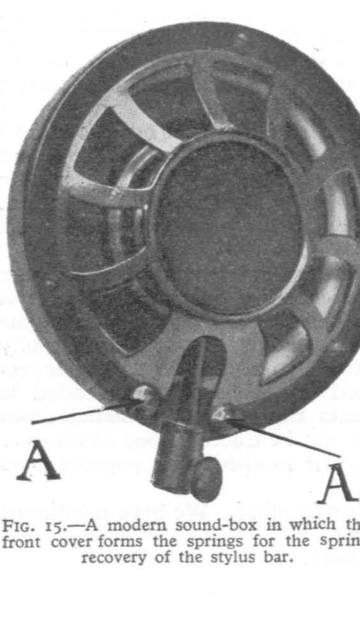

FIG. 15.—A modern sound-box in which the front cover forms the springs for the spring recovery of the stylus bar.

The illustration Fig. 14 is of a composite sound-box in which the stylus bar is mounted on pivots. Figs. 15 and 16 are of a modern commercial sound-box—the Meltrope—in which the stylus is mounted on four steel balls. It will be readily seen by referring to Fig. 16 how the cover of this box forms the springs for the spring recovery of the stylus bar. The two points A in Fig. 15 correspond with the points A in Fig. 16.

(5) Sound-boxes in which the stylus bar is mounted on end pivots are usually more prone to buzz than spring or ball-mounted stylus bars. The reason is that the pivots wear slightly and thus work loose ; changes of temperature also affect the setting. The pivots should be delicately adjusted so that there is no end play and yet the stylus bar must be free. Too tightly adjusted pivots are just as bad as loose ones. Any one who understands metal turning and fitting will know at once how to adjust these pivots to a nicety. Be careful to see that the pivots do not slip when tightening the small lock nuts. Apart from buzzing, one effect of too tightly adjusted pivots will be to limit the response of the sound-box to both high and low notes.

(6) If you have any reason to suspect the rubber gaskets of the sound-box replace them immediately. Hard or perished gaskets give a hard tone and cause an extraneous whistle. It is essential that soft pliant rubber be used. When the gaskets are placed in position there should be no gap between the two ends, neither should they overlap ; they should be of the *exact* length required to go round the inside of the back plate.

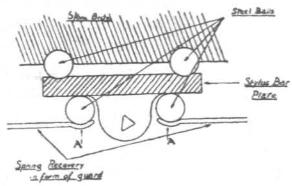

FIG. 16.—Diagram showing four ball suspension of stylus bar plate of sound box shown in Fig. 15.

(7) In this case the joint can be made air tight by thin rubber wrapped round the neck of the sound-box in continental type boxes, and on those with bayonet type fittings the tone-arm end can be covered with thin rubber, or preferably a smaller bore rubber ring can be inserted in the back plate aperture. An air leak at this juncture of the acoustic system will have devastating effects on the tone. The volume will be reduced, the tone will become backward and more important still there will be a loss of low notes.

Conclusion.—Other points that have an adverse effect on records and reproduction are bad alignment, an instrument that is not level, too large or too small a needle angle, and a sound-box that, when fitted to the tone-arm and resting on the record, is not at right angles to the record. All these are dealt with elsewhere in this little book and all are of vital importance.

The tuning of sound-boxes is best left to the experts as it is a matter which calls for a great amount of experience and fine judgment ; it is not to be learned in a week or even a year. All the points about the levelling of your instrument, the freedom of the tone-arm, faulty automatic breaks, or anything which tends to retard the lateral movement of the tone-arm across the record are especially commended to fibre needle enthusiasts. In many cases the constant breaking down of fibre and non-metallic needle points can be traced to one or other of these defects. A motor which is irregular in speed also imposes extra strain on the points of all needles.

Finally keep the following rules always in mind. We have mentioned them before but they are worth repeating.

(*a*) See that your instrument is level.

(*b*) Keep your records scrupulously clean.

(*c*) When replacing your sound-box on the tone-arm make certain that the face is at right angles to the face of the record.

(*d*) Also see that the needle angle is approximately 60 degrees. A 60 degrees set square can easily be made out of stiff cardboard or alternatively buy one from E. M. Ginn or E.M.G. Handmade Gramophones Ltd., they only cost a few pence.

(*e*) Examine the joint between the tone-arm and horn periodically making sure that it is air-tight. To ascertain this, stuff a duster tightly into the horn mouth and blow tobacco smoke through from the tone-arm.

(*f*) Lubricate the motor at least once in three months. Don't drown it.

(*g*) Keep the governor pad clean and soft.

(*h*) Keep the gears of the motor free from grit.

(*i*) Don't wind up the motor while playing a record.

(*k*) Don't start the motor with a flick of the hand or you may strain the governor springs.

CHAPTER VII.

Records.

Buying Records.

It is not an exaggeration to say, despite the increased number of different makes, that the buying of records has become a totally different proposition during the last two or three years. The musical press have taken the gramophone into their domain and now publish authentic record reviews; the wireless press have emulated the musical press and even the daily papers now include record reviews in their columns. But the most comprehensive of all record reviews are published in *The Gramophone* which, by the way, was started with the review of records as its sole object. Nothing could be more illusory than a mere consideration of titles and artists in a catalogue, and in the old days one used to have quite a large percentage of disappointments unless one was in the happy position of being able to hear records before buying them. Now there is no excuse for disappointment.

There are several firms who will send records on approval. There are dealers in many towns who hold monthly recitals of the new issues. There are also many gramophone societies which do the same. The B.B.C. broadcasts nearly all the important records in the course of the month; these recitals are principally conducted by Mr. Christopher Stone. But in any case it is always wise to hear the records for yourself in a gramophone shop if you can. Most progressive gramophone dealers provide audition rooms or cubicles for these purposes now-a-days.

When you go to buy records, go with a list in your hand or a very clear idea in your head of the records you wish to try. Notice whether the records you hear are warped or whether they are swingers. In the former event ask for another copy of the record which is not warped. The swinger is a more serious matter; it means that the hole is not precisely in the centre of the record grooves. In that case the sound-box will sway from side to side and the tone will waver just as if the motor speed was irregular. A record may be true on one side and out of centre on the other. Never buy a swinger on any account. But do not despair; it is quite possible that the assistant will find one that is correctly centred on both sides. Often, too, the hole is rather large for the spindle of the gramophone you are using, and in that case you can move the record slightly so as to obliterate the swing with a little tap on the rim at the moment when the sound-box is veering outwards. If the hole is too large for your own particular gramophone spindle then get a "Centrelock" made for this purpose by E.M.G. Handmade Gramophones Ltd.

One point about buying records at your local dealer's should always be borne in mind. If the dealer demonstrates with steel needles it may happen, especially if he does not take particular care to keep his instruments in perfect condition, that the stock of records gradually becomes worn. Many a record has already received its death sentence before it leaves one of the less well-managed shops. For this reason it is now becoming common for the progressive dealer to demonstrate with fibre needles only using sound-boxes specially tuned for the purpose. In other cases it is always wise to examine the record for signs of premature wear. Hold the record slantingly up to the light and see if you can detect any sign of grey lines in the grooves. If you can, the record is worn, and you will be justified in rejecting it. Similarly if you should notice any of the major record faults described in Appendix I you would be well advised to ask for another copy.

Building up a Record Library.

The golden rule about records is that the really expensive records are those which you will not enjoy equally in a year's time and those which wear out quickly. The wise man makes his collection laboriously, methodically, lovingly; the fool makes his pile of records spasmodically, irrelevantly, ecstatically. The recording companies make their profits out of the fools. Long live folly, O wise man, for thy sake!

Cultivate the reasoned enthusiasm of the book collector. Read up all about a record before you decide to buy it; when bought, treasure it for the value that you know lies in it. This is not a lecture, but the outcome of reading letters from dozens of people who have collected hundreds of records, each one of which is still as precious as when first bought.

As to the life of records, this is a thorny subject. It all depends on the particular type and make of record and on the conditions under which they are played. But the art of recording and the mixing of record material and the means of reproduction are all steadily improving and these improvements tend to prolong the life of a record rather than shorten it.

Storing and Cataloguing Records.

While you have only a few dozen records, you can help keep them in albums or small record cabinets like the Rondo, "Popular" model. This incorporates a special indexing system and holds fifty 12 inch records. But when your collection runs into hundreds, you will have to adopt a system. Probably the best and simplest is that which is described on page 65. But you may not have the time nor the inclination to make this, and you may prefer to buy a cabinet ready made. There are three or four different systems, and each has certain points to recommend it. The E.M.G., the Sesame, the Rondo "Bildup" and the Roladisc are the best known. The last two store records in an upright position, while the E.M.G. and the Sesame store them flat but present them upright.

Best Records.

Choosing records for other people is a thankless business and the only excuse for these notes is that there are many thousands of records in the catalogues to bewilder the layman so that a little tentative advice on the subject may be useful.

The following lists have been compiled by the reviewers of *The Gramophone* and represent their particular recommendations of records to form the nucleus of an "evergreen" library.

Is a reminder necessary that a list of this sort is only up-to-date, and even then is by no means exhaustive?

Orchestral and Chamber Music.

Moussorgsky: *Prelude to Khovanchtchina* and *Flight of the Bumble Bee;* Col. DB9908.

Dvorak: *Carnival Overture;* H.M.V. D1796.

Herbert: *Irish Rhapsody*; H.M.V. C1889.
Elgar: *Violin Concerto*; Col. L2346–51.
Elgar: *Part of Crown of India Suite*, and *Pomp and Circumstance March No. 5*; H.M.V. D1900.
Delibes: *Sylvia Ballet Music*; Col. LX114–5.
Beethoven: *Leonore No. 3*; Col. LX129–30.
Warlock: *Capriol Suite*; Decca K576.
Mozart: *Finale of Piano Concerto in F*; Parlo. E11124.
Schumann: *Manfred Overture*; Parlo. E11131–2.
Elgar: *Nursery Suite*; H.M.V. D1998–9.
Dohnanyi: *Suite Op. 19*; H.M.V. D1902, 3, 4. (Connoisseur).
Liadov: *Eight Russian Fairy Tales*; H.M.V. D1811–12. (Connoisseur).
Berlioz: *Royal Hunt* and *Storm*; Col. DX291.
Sibelius: *Movements from Karelia Suite*; Col. DX307.
Haydn: *Quartet Op. 76, No. 1 Poltronieri S.Q.*; Col. 9777–8.
Mozart: *Quintet in A, Clarinet and S.Q.*; Col. 2228–32.
Mozart: *Clarinet Trio in E flat No. 7*; (K. 498) N.G.S. 161–2.
Schubert: *Quartet Op. 161*; (Flonzaley); H.M.V. DB1373, 4, 5, 6. (Connoisseur).
Dvorak: *Piano Quintet*; Col. LX150–3.

INSTRUMENTAL.

Niedzielski: *Chopin Mazurkas*; H.M.V. C2008–9 and H.M.V. B3550, C2010 (Any).
Gieseking: *Beethoven Sonata in D minor* (Op. 31.2); Col. DX277–8.
Rudolph Dolmetsch: *Purcell Suite in G Minor*; Col. DB680.
Murdoch: *Sibelius Valse Triste* and *Grieg's Bridal March*; Col. DX314.
Alfred Sittard: *Handel Organ Concerto in F major*; Polydor 95428.
Szigeti: *Bach Violin Sonata No. 1 in G. minor* (Solo); Col. LX. 127–8.
Kreisler: *Couperin, La Precieusa* and *Chanson Louis 13*; H.M.V. DA1139.
Egon Petri: *Liszt: Valse Impromptu in A major*; H.M.V. B3718.
Cassado: *Bruch: Kol Nidrei*; Col. LX131.
Lamond: *Beethoven: Waldstein Sonata*; H.M.V. D1983–5.
Edith Penville: *Purcell: Air* and *Hornpipe*; Col. DB398.
Joan Massia and Blanche Selva: *Cesar Franck: Violin Sonata*; Col. DX239–42.

OPERATIC.

La Sonnambula (Bellini) and **Falstaff** (Verdi): *Toti Dal Monte*; *Ah! Non credea mirarti* and *Sul fil d'un soffio etesio*; H.M.V. DB. 1317.
Marriage of Figaro (Mozart): *Elisabeth Schumann*; *Venite, inginoocchiatevi* and *Non so più cosa son*; H.M.V. DA844.
Lohengrin (Wagner): *Lotte Lehmann*; *Elsa's Dream* and *Elsa's Song to the Breezes*; Parlo. RO20113.
Die Meistersinger (Wagner): *Elisabeth Rethberg* and *Friedrich Schorr*; *Suh' Ev'chen! Ducht' ich doch* and *Hat mann mit med Schulwerk*; H.M.V. B1421.
Magic Flute (Mozart) and **Tannhäuser**: *Gerhard Husch*; *Papageno's Song* and *Blick' ich umher*; Parlo. E11046.

Die Fledermaus (Strauss) and **La Bohème** (Puccini) : *Heddle Nash* and *Dennis Noble ; Come with me, no risk you run* and *Ah, Mimi, false, fickle-hearted ;* Col. DX212.

La Traviata (Verdi) : *Olga Olgina ; Ah ! fors' e lui ;* Decca K570.

Don Giovanni (Mozart) : *Miriam Licette ; Batti, batti* and *Mi tradi quell'alma ingrata ;* Col. 9911.

Otello (Verdi) : *Emanuele Salazar ; Monologo* and *Niun mi tema ;* Col. L2365.

Die Meistersinger (Wagner) *: Quintet, Elisabeth Schumann, Lauritz Melchior, Frederich Schorr, Gladys Parr* and *Ben Williams ;* H.M.V. D2002.

Die Fledermaus (Strauss) : *Lotte Lehmann ; Mein Hur was dachten Sie von mir ?* and *Klange der Heimat ;* Parlo. RO20171.

La Gioconda and Pearl Fishers (Bizet) : *Gigli and de Luca ; Enzo Grimaldo ; Principe di Santafor* and *Del tempio al limitar ;* H.M.V. DB1150.

BAND.

Die Meistersinger Selection : *Grenadier Guards Band ;* Col. 9424.

Zampa Overture : *Grenadier Guards Band ;* Col. DX308.

March of the Knights of the Holy Grail (from Wagner's Parsifal) : *Grenadier Guards Band ;* Col. DX75.

Tales of Hoffmann Selection : *Coldstream Guards Band ;* H.M.V. C 2092.

Le Père la Victoire and Sambre et Meuse Marches : *Garde Républicaine Band ;* H.M.V. B2908.

American Suite : *Coldstream Guards Band ;* H.M.V. C2335.

Silver Trumpets, Grand Processional March : *Grenadier Guards Band ;* Col. DB714.

The Thin Red Line and Punjab Marches : *Massed Military Bands ;* Parlo. E6132.

Light Cavalry Overture : *Massed Military Bands ;* Parlo. E6132.

Marche Lorraine and Blaze Away Marches : *Welsh Guards Band and Male Chorus ;* Broadcast " Twelve " 3086.

Hungarian Rhapsody No. 1. : *Welsh Guards Band ;* Broadcast " Twelve " 3115.

Sonata Pathetique (Beethoven) : *Brighouse and Rastrick Band* (*Brass*) ; Decca F. 1074–5.

SONGS.

Florence Austral : *Rose Softly Blooming* and *Alleluia,* the *Easter Hymn* and the *Vesper Hymn ;* H.M.V. E561, E593.

Isobel Baillie : *Shepherd on the rock* (Schubert) with Charles Draper, clarinet and *O, had I Jubal's lyre* (Handel) ; Col. 9613, 9697.

Essie Ackland : *Ombra mai fù* (Handel's "Largo") ; H.M.V. C1599.

Muriel Brunskill : *Sea Wrack* (Harty) ; Col. 9687.

Esther Coleman : *Ombra mai fù ;* Zonophone 6166.

Annette Blackwell : *Nursery Rhymes ;* Col. DB706.

John McCormack : *Irish Folk Song* and *Two Parry Songs ;* H.M.V. DA1171, DA1172.

Kennedy McKenna : *Scottish Folk Songs, Corn rigs* and *Ca' the yowes ;* Winner (Edison Bell) 4984.

Heddle Nash : *Deeper and deeper still* and *Waft her, angels* (Handel) ; Col. DX295.

Frank Titterton : *Sound an Alarm* (Handel), *Now sleeps the Crimson Petal* (Quilter) ; Decca K594 and F2187.

Stewart Wilson : *Phillida flouts me, Keys of Canterbury ;* Decca F1830, F1835.

Keith Falkner : *How Jovial is my Laughter* (Bach), *Had a Horse ;* H.M.V. B3581, B3105.

Roy Henderson : *Ethiopia saluting the Colours* (Charles Wood), *Eleanore* and *Border Ballad ;* Decca F2462, F1699.

Stuart Robertson : *I have twelve oxen* (Ireland), *Green grow the rashes O ;* H.M.V. B3411, B6034.

Dale Smith : *Widdicombe Fair* and *On Ilkla Moor ;* Decca F2737.

John Thorn : *The Crocodile* and *Pretty Polly Perkins of Paddington Green* (with chorus) ; Imperial 2657.

Sir George Henschel (accompanying himself) : *Heinrich der Vogler* and *Der Erlkönig ;* Col. L2303.

Norman Allin : *Awake! Ye Dead* (Purcell) (duet with Harold Williams), *Midnight Review* and *Edward ;* Col. 5438, 9874.

Paul Robeson : *Negro Spirituals ;* H.M.V. B2619, 2126, 2727.

Tom Burke : *Toselli's Serenata ;* Imperial Z120.

Albert Richardson : *The Old Sow ;* Zonophone 5178.

CHORAL.

B.B.C. National Chorus : *The heavens are telling* (Haydn), *The Austrian Emperor's Hymn to Glorious things ;* Col. DX333.

Westminster Abbey Choir : *Blessing, Glory & Wisdom* (Bach's motet) ; H.M.V. C1850.

Manchester School Children's Choir, with the Hallé Orchestra, conducted by Harty ; Col. 9909.

The Decca Choir : *English Part Songs ;* Decca F1714.

Royal Choral Society : *Hiawatha's Wedding Feast* (Coleridge Taylor); H.M.V. C1931-4.

Philharmonic Choir : *Mass in B Minor* (Bach), *Et in Spiritum Sanctum* (solo), *Sanetus* (choral) ; H.M.V. C1715-16, 1722, 1724.

MISCELLANEOUS.

It is impossible owing to the multiplicity of titles to give record lists of the lighter type of music—dance, light vocal and orchestral items—but the bulletins published monthly by the various recording companies, and obtainable gratis from almost any dealer, will help considerably in making selections of your own. The Imperial lists, for example, provide some excellent fare for parties and the like and the records are really so inexpensive that one can almost treat them much in the same way as the ordinary gramophone needle ; and cast them aside when tired of the tunes in favour of the even more up-to-the-minute titles.

Chapter VIII.

BUYING A RADIO-GRAMOPHONE.

It is not so many years ago that the adherents of gramophones and broadcasting were engaged in a fierce controversy as to the merits of their respective hobbies. To some extent the argument still persists; the gramophiles claim that their individual control over the programmes is an advantage not to be denied and even go so far as to assert that for sheer quality the acoustic gramophone, with its freedom from external interference, has the radio receiver beaten every time; on the other hand, the radio fans point to the improved reproduction at the bass end of the scale that has been made possible by the moving coil speaker, the ease of volume control and the general "naturalness" of the quality that a modern radio receiver gives.

As is not unusual in all such controversies there is a good deal to be said on both sides. Fortunately it is no longer necessary to enter into any extensive analysis of the arguments used since the advent of the radio-gramophone, and the very considerable improvements in design made during the past few years, are rapidly robbing the acoustic diehards of what is perhaps their chief advantage: the choice of programme. There can now be little doubt that ultimately the radio-gramophone, with its power of reproducing either records or radio, will hold the field to the virtual exclusion of either acoustic gramophone or straight radio-receiver. It should, however, be remarked even at this date:—

(1) that the best gramophones give a certain delicacy, refinement and compactness of tone that is missing from at any rate most radio-grams;

(2) that unless one has electric light available in one's home the attainment of a good standard of quality in electrical reproduction is a matter of some difficulty—and expense;

(3) that the acoustic gramophone, having fewer component parts, is less likely to go out of order; so that unless one lives in a locality where "service" facilities are available, if required, the acoustic gramophone is more reliable.

Before deciding, therefore, whether to buy a gramophone or a radio-gramophone you should take into consideration the following points:

(1) If you have no electricity in your house you should avoid the radio-gram. Unless you are an expert, you will certainly encounter great disappointments if you try to run an instrument of this character from batteries.

(2) As a rule the very cheap radio-grams are a snare and a delusion.

(3) If your means limit you to the purchase of one of the less expensive instruments do not be misled by claims that on the radio side a multitude of foreign stations can be received. Satisfactory distant reception cannot at present be combined with the best quality in a cheap instrument. So be content with good reproduction from records and from the local broadcasting stations, and from one or two of the more powerful foreigners. Good distant reception *can* be combined with excellent quality but only at a price.

(4) Similarly, do not expect to obtain large volume without paying for it. Much of the bad quality one hears from the smaller radio receivers and radio-gramophones is due to the

desire to show off in the matter of volume. If the quality is bad, more of it is worse.

(5) On the other hand if you prefer your music to be very quiet you will usually find that the acoustic gramophone will give better quality than the radio-gram. The reason is that most moving coil loudspeakers (which are the ones usually used) work most effectively at a volume level greater than that of a good gramophone. This, however, does not apply in the case of large horn loudspeakers operated by moving coil driving units.

(6) In either case, though it is specially important in the case of the radio-gram, do not buy an instrument which is not made by a reliable British firm. If you do, you may have endless trouble if anything should go wrong.

Suppose now that you set out one evening to buy a radio-gram. What tests would you apply? If your knowledge of such instruments is only meagre then you would be at the mercy of the wily salesman. What follows is a collection of simple hints and tests which should be of considerable help. Perhaps the best plan is to hear an orchestral record on one or two instruments first of all, to give you a rough idea of the tonal balance of each. But choose a record of a tune you are familiar with. Then having formed a rough conception of the merits of each, proceed to apply the following tests. Test the motor first for unseemly noises. Mechanical noises are bad enough, but electrical noises are much worse, since they may be amplified by the instrument. Have the instrument switched over to "gramophone" and with the motor running and the volume control at its maximum setting, take notice of the amount of hum coming from the speaker. It should only be audible when your ear is fairly close to the speaker grille. Now switch the motor off. There should be no appreciable difference. Next, hold the pick-up over the centre and close to the revolving turntable. If the motor is of the universal type (A.C. or D.C.) there may be crackling noises in the speaker. If so, the motor produces what is known as "electrostatic interference" which was referred to in the notes on electric motors on page 25. Now switch over to radio and with volume control still full out and with the motor running, notice whether the crackling noises still persist. If so, you can assume that there is "radio frequency" interference. Make sure to apply this last test with the receiver portion switched over to both the long and medium wavebands. Sometimes radio frequency disturbances are prevalent on the long waveband only, according to the construction of the commutator of the motor. If these electrical disturbances are manifest have nothing more to do with that particular instrument. Motors that behave like this are a public nuisance. They act as miniature broadcasting stations and the cracklings may be picked up and amplified by every wireless set in the vicinity. But in fairness to the dealer and to the instrument it should be noted that if the crackling is present when switched over to radio with the motor stationary, the trouble is probably due to external interference; trams, electric machinery or atmospherics. As to this you can only accept the dealer's word so make a mental note to apply similar tests in your own home.

If the motor comes through the ordeal with flying colours, turn your attention to the record reproducing side of the instrument. Here you must insist on hearing records of your own choice. Take a selection of your own records with you, or if you do not possess any, ask a friendly gramophile to accompany you. If perchance this is impossible, then read

FIG. 17.—The Columbia Radio-Gramophone. Model 602.

FIG. 18.—The H.M.V. Radio-Gramophone. Model 501.

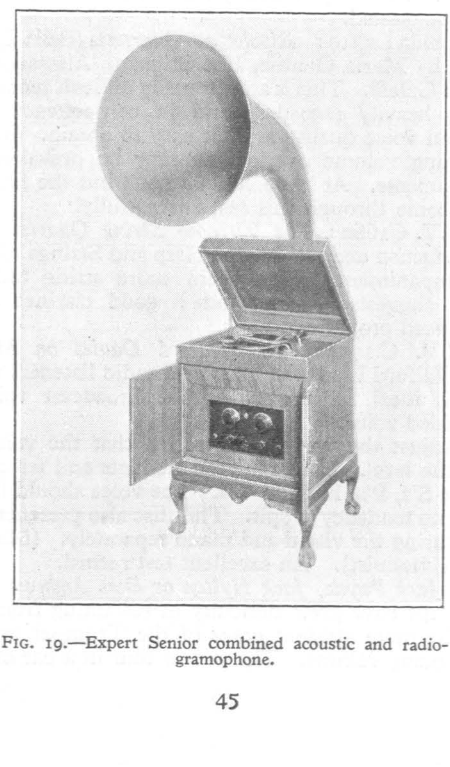

FIG. 19.—Expert Senior combined acoustic and radio-gramophone.

through the following list and note the salient features to listen for. Do not try to memorise them; take the list with you. With each record you choose to hear, ask the demonstrator to adjust the volume to your own liking. This is absolutely necessary, as you will find, for rare is the salesman that has any idea but to impress you by *The Storm* at its maximum violence.

(1) Parlophone R20130: *Conchita Supervia*—Mezzo Soprano, singing *Granada* (Albeniz-Cuenca); in Spanish. With this naturally forceful record set the volume control so that the volume is above the normal required for comfortable listening. If the instrument has a good reserve of power there will be no signs of overloading (distortion of the voice) when the artist sings the higher notes.

(2) H.M.V. DB1165: *Galli-Curci and De Luca* singing *Dite alla giovine* from *La Traviata*. This is a glorious record for tone and delicacy. The duet is beautifully rendered.

(3) Columbia 9929: *Norman Allin*—Bass, singing a song by Purcell from *The Tempest* (Arise, ye subterranean winds). Most pick-ups will find it difficult not to "chatter" on certain passages in this record. The accompanying bass strings in the first part of the disc should be quite clean, not boomy.

(4) H.M.V. D1470: *Trial by Jury* (Swear Thou the Jury and Where is the Plaintiff). Angelina, the plaintiff in the case, is called into court by the Usher, her name being repeated in exactly the same manner in the corridor. Listen carefully for the fourth Angelin-ah. The -ah can be distinctly heard on first-class reproducers, but on mediocre instruments it is only suggested.

(5) Columbia L2310: *Rigoletto—Quartette* (Bella figlia dell'amore), sung by Maria Gentile, Ebe Stignani, Alessandro Granda and Carlo Galeffi. This is an extremely difficult record to reproduce. It is heavily recorded, and in consequence definition and natural voice quality are not easy to obtain. Even at ordinary listening volume overloading may be prevalent on mediocre instruments. At large volume none but the finest instruments will come through this test successfully.

(6) H.M.V. C1662: *The Virtuoso String Quartet* playing *Ravel's Introduction and Allegro* for Harp and Strings with Wood-Wind accompaniment. Here again more string tone and, as the label suggests, clarinet tone; good clarinet tone when reproduced properly.

(7) H.M.V. C.1759: *Sir Walford Davies on Melodic Outline.* Sir Walford is so well known to radio listeners that this record seems ideal for comparing the broadcast voice against the recorded voice.

Adjust the volume control so that the voice is at natural volume level. Listen for the sibilants and fricative consonants—the S's, P's, K's and T's. The voice should be quite smooth with no tendency to spit. This disc also presents an opportunity of hearing the violin and piano separately. (Marjorie Hayward is the violinist). An excellent test record.

(8) *Any Jack Payne, Jack Hylton or Bert Ambrose* record. Many pick-ups have great difficulty in refraining from "chattering" on the more strident notes of the Trumpet when reproduced at dancing volume. The two or four in a bar of the bass drum

should be quite clean and definite. It is comparatively easy to reproduce a roll of the tympani on either electric or acoustic instruments, but the transient-like notes of the bass drum (usually damped) of a dance band are not so easy.

(9) Columbia L2207: *Joseph Szigeti* playing *Caprice No.* 24 (Variations in A Minor). This presents an opportunity for judging the quality of string tone. If the disc is faithfully reproduced quality is excellent. The latter part of the second side can be used as an indicator of the high note response of the instrument. That elusive thing, quality, is the principal feature of the record.

(10) Columbia DX314: *William Murdoch* playing *Sibelius's Valse Triste.* As most of you know, the piano is probably the most difficult instrument to record or reproduce. Here is splendid piano tone. At no time throughout the playing of this side should the tone sound "wooden" or the bass notes be very resonant. In short listen for natural piano tone.

Add to this list the two orchestral records mentioned in connection with "Buying an Acoustic Gramophone" on page 7 and notice carefully the definition and the timbre of the various instruments, especially the "skin" quality of the tympani. Then, while a loud passage is being played set the volume control at its *minimum* setting so that no sound comes from the loudspeaker and listen to the amount of needle chatter and buzz from the pick-up. There is bound to be slight needle noise but it should not be too prominent.

To satisfy yourself about the radio side, insist that the instrument be temporarily installed in your own home. Most reliable dealers will readily consent to do this. It is important that you hear it under home conditions as the reception of foreign broadcasts depends to a certain extent on the locality. Even if you are not interested in foreigners it is essential to test the instrument on your own mains, as there is always the possibility of a variation in hum when the instrument is connected to other mains. As regards the actual quality of radio reproduction, listen for the same points indicated in the record list. A good instrument usually gives rather better radio reproduction from the local station than when playing records.

Chapter IX.

POINTS IN RADIO-GRAMOPHONE DESIGN.

General.

As with most other things, the virtues one looks for in a radio-gramophone are largely matters of individual taste. One person may consider that an instrument which will get "High Street China" and all the stations in between at good volume (and mediocre quality) is the acme of perfection. Another is quite content to receive the local station and one or two foreigners so long as the quality of reproduction of radio and gramophone records attains his particular standard. Fortunately, there are indications that before long quality reproduction and station getting propensities will be common to all the better known makes of instrument.

It is not proposed here to go into all the whys and wherefores of radio-gramophone design. There are a number of features, however, of common interest to both the technical and non-technical user, and a certain amount of explanation appears desirable to ensure both wise purchase and intelligent operation. It is not suggested that everyone should be thoroughly familiar with the various processes (any more than they should have an intimate knowledge of the innards of the clock which stands on their mantlepiece) but merely that they should have a general idea of what it is all about.

The Five Operations.

In a radio-gramophone there are in general five distinct operations apart from that performed by the loud-speaker. Only two of these are needed when gramophone records are being played, while four of them are concerned with radio reception. These operations are :—

(1) The conversion of mechanical vibrations imparted by the record to a gramophone needle into electrical vibrations. This is done by means of an electric pick-up and, of course, is not in operation when radio is being received.

(2) The tuning in of a broadcasting station.

(3) The amplification of the signals as tuned in. This is known as high-frequency (H.F.) or radio-frequency amplification.

(4) The detection (sometimes called demodulation and sometimes called rectification) of the radio-frequency signals, whether amplified or not. The object of this is to separate out the speech frequencies from that used by the broadcasting station (the "carrier" frequency) to distinguish the transmission from that of other stations.

(5) The amplification of the electrical vibrations as received from the detector stage, or from the electric pick-up. This is known as low frequency (L.F.) or audio frequency amplification.

L.F. Amplifier.

The only process common to both radio reception and gramophone reproduction is that numbered (5), the L.F. amplification. This amplification may be in several "stages" ending with an "output" stage which must have a large power handling capacity since it has to provide the loudspeaker with comparatively large currents. It should be noted, however, that by suitable arrangement of switches it is possible to use the radio detector as the first stage of L.F. amplification when the amplifier is used on gramophone pick-up. This is not a universal practice but it has advantages when a pick-up with a low electrical output is used (and such pick-ups are in some ways the best), or when very large output power, and therefore a high degree of amplification is required.

It should be emphasised that the power which an amplifier is capable of giving depends in practice more upon the characteristics of the last, or output, valve than upon the number of valves used. This is a point that puzzles most ordinary people: they imagine that a receiver which has 9 valves must be much more powerful than one with only 3. That is not so. It is usually much more *sensitive* but not necessarily more powerful. The level of power output is determined rigidly by the handling capacity of the last valve; the earlier stages of amplification only serve to magnify weaker and weaker signals up to that level; they cannot magnify a strong signal to a point above that level without distortion. Assuming therefore that the amplifier is reasonably well designed to amplify vibrations of different frequency in the same proportion, the important point to look for in a L.F. amplifier is the power handling capacity of the last valve. This is usually expressed by the makers as so many watts or milli-watts undistorted output; thus a 1932 Marconi-Osram PX. 4 valve is capable of giving about 2 watts, or 2,000 milliwatts undistorted output. Sometimes, however, this figure is not given but only the "maximum anode dissipation"; in that case one reckons with modern power valves that the undistorted output is about one fifth of the anode dissipation. It is convenient to know in this connection that with moving coil loudspeakers of average efficiency, the undistorted power required for satisfactory reproduction is as given in the following table:—

TABLE OF OUTPUT POWER.

Conditions.	Radio.	Records.
Small Room; say 10ft. × 12ft.	350 Milliwatts	1,000 Milliwatts.
Larger Room; say 15ft. × 20ft.	1,500 Milliwatts.	3 Watts.
Small Dance Room; 30ft. × 40ft.	5 Watts.	10 Watts.
Concert Hall; 100ft. × 150ft.	15 Watts.	30 Watts.
Ballroom 200ft. × 250ft.	40 Watts.	60-100 Watts.

When more power is required than a single valve will give, it is common practice to use 2 or more valves in the last stage, arranged either in parallel or what is known as "Push-pull." From many points of view the latter arrangement is to be preferred. In either case, however, the arrangement is simply equivalent to a single valve of larger capacity.

There is one other point that should be noted about the output valve. It is becoming common nowadays to use a Pentode valve for this purpose. The reason is that a Pentode gives a relatively large output power for a small input, and therefore it is usually possible by its use to save one earlier stage of amplification. Fortunately, the pentode itself corrects for one of the most important amplifier losses. A high degree of amplification *per stage* in an amplifier usually leads to considerable high note loss; the pentode, on the other hand, is more sensitive to high notes and therefore by judicious mixing a right balance can be preserved in this respect. There are, however, other disabilities which have not yet been completely overcome, notably in the way in which vibrations of different strengths are handled. As a rule, then, it may be said that the quality of reproduction with a pentode is inferior to that with an ordinary super-power valve, properly used. But the difference nowadays is such that a side by side comparison is often needed before one can appreciate it.

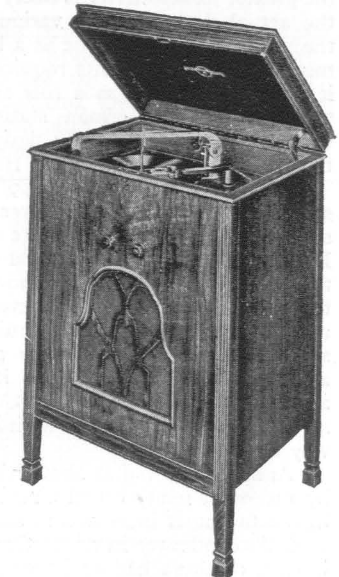

FIG. 20.—The Columbia automatic radio-gramophone Model 604.

The Detector.

Little need be said here about the merits of different types of detector stage. It often gives the designer much trouble, particularly in the elimination of mains hum, but perhaps the only point that concerns the ordinary user is that the detector valve is operating in a very sensitive state, and therefore a change of valve (of the same type) in this position may improve or mar the quality of the reproduction.

H.F. Amplification and Tuning.

The H.F. amplification in a receiver is somewhat complicated by the fact that tuning is to a large extent mixed up with it. Its purpose is two-fold: (*a*) to increase *sensitivity, i.e.,* to amplify the signal as received from the broadcasting station to such an extent that the detector stage is adequately fed. A greater degree of H.F. amplification is therefore needed for a weak or a distant station than for a strong or nearby station; (*b*) to increase *selectivity, i.e.,* the ability of the receiver to distinguish between different stations broadcasting on different wave-lengths (or frequencies). (Note.—the wavelength of a station multiplied by its frequency is constant—the velocity of light). This is really the function of the tuning: the more tuned circuits there are, the greater in general is the selectivity. Tuned circuits may be placed either before an H.F. stage, between two H.F. stages or between an H.F. stage and the detector stage. It follows, therefore, that the more H.F. stages a receiver has the greater its selectivity is likely to be; this is not always the case, because the actual design of the various stages has an important bearing upon the matter; but it is true as a broad generality. As an indication of the number of tuned circuits required to give a required degree of selectivity, it may be said that as a rule seven tuned circuits are needed in London to separate the German station Muhlacker from London Regional; whereas only one properly designed circuit, or at most two, is required to separate London Regional from Muhlacker.

Unfortunately, it must also be said that as a rule an increase in the selectivity of a receiver involves a diminution of the high note response; so that highly selective sets are apt to be correspondingly poor in quality. By coupling together the tuned circuits in a certain manner, now referred to as "band-pass tuning," however, it is possible to mitigate this unfortunate effect to a large extent. The result is that in those modern receivers where band-pass tuning has been employed, a high degree of selectivity coupled with very good quality has been achieved. It has also been demonstrated that it is possible to compensate in the L.F. amplifier for high-note loss in the tuning without upsetting the selectivity; so that the problem of combining quality with selectivity is well on the way to solution.

Another point that should be noted about this increase of selectivity by means of many tuned circuits, is that thereby the number of variables in the tuning is increased at the same time. Every tuned circuit needs a variable condenser in order that a range of stations may be covered, and if each of these had to be controlled independently, the operation of a highly selective receiver would indeed be a complicated affair. In practice, therefore, arrangements are made to gang the tuning condensers together so that some or all of them are controlled by a single knob. Ganged condensers are essential for band-pass tuning if the special band-pass effect is to be obtained for all settings. The design of a receiver with ganged tuning is a delicate affair, demanding great accuracy in the design and manufacture of the various components as well as consistency in assembly. Inaccuracies may affect both quality and sensitivity.

Super-Heterodyne Receivers.

It is perhaps for this reason that a return is being made to a form of H.F. amplification which was used many years ago, but went out of favour for a number of reasons which now no longer apply. This is known as the super-het. Its advantages are that a high degree of amplification and of selectivity can be secured with but few variables in operation. Thus it is common to have 3 amplification stages with 8 or more tuned circuits, 6 of these being pre-set and invariable and only 2 requiring adjustment during the operation of tuning in a station; the 6 pre-set circuits are arranged in 3 pairs each pair constituting a band-pass arrangement. In this way a very high degree of selectivity is secured with a minimum of high note loss and very few controls.

Number of Controls.

For the ordinary person obviously the fewer controls and therefore the fewer operations to perform, in a radio-gramophone the better. The minimum number required is 3, namely :—

(*a*) Tuning control.
(*b*) Volume control.
(*c*) Switching control.

As already indicated a single tuning control involves the ganging of a number of tuned circuits. In the H.M.V. Super heterodyne radio-gramophone No. 531 for instance, there are ten tuned circuits, six of them being pre-set, and only one tuning control. Obviously, a volume control is also needed since the signal strength of different stations varies widely in any particular locality. To have only one control again usually involves ganging, since the variation of signal strength is so very large

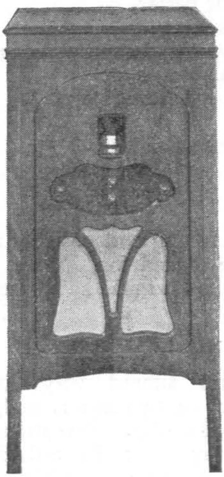

FIG. 21.—A super-heterodyne radio-gramophone. The Marconiphone Radio-Autogram. This is fitted with a record changing unit.

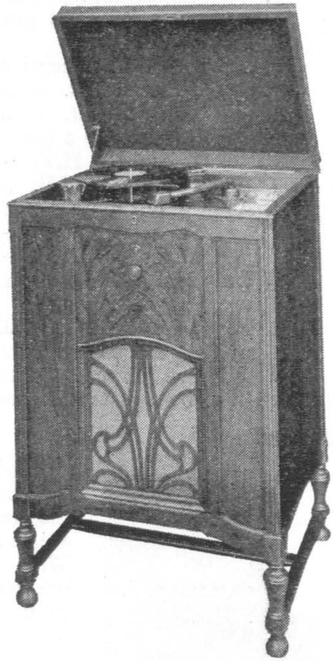

FIG. 22.—The H.M.V. Super-Heterodyne radio-gramophone with automatic record changer.

that no single method of control is feasible if quality is to be maintained. To assist in this, an independent local-distant station switch has also been added in the H.M.V. 531 ; this complicates the operation but little and adds considerable to the flexibility of the receiver. In any case, however, it is clearly desirable that the same volume control should be effective both on radio and on gramophone. The switching operations that are to be performed are : on and off, long waves to medium waves, and radio to gramophone. All these operations can be controlled by one knob, but sometimes it is more convenient to combine the on and off switch with the volume control knob.

One further point should be noticed. It does not much matter where the tuning and switching controls are situated so long as they are easily accessible when wanted. The control of volume however, may be (and often is) required whilst one is listening to a piece of music, and it should therefore be placed on the outside of the cabinet so that one need not have to lift the lid and fumble about to make the adjustment. Some manufacturers go one step further and provide, in addition, a remote volume control which can be operated from one's chair. Such a refinement is all to the good.

SUMMARY.

As a summary of the foregoing discussion we may postulate the following requirements in a radio-gramophone :—

1. The undistorted power output should not be less than 1,500 milliwatts for good gramophone reproduction; and 2,000 or more is better.
2. Local Station Reception only:
   Tuner + det. + Output stages; or better,
   Tuner + det. + L.F. + Output stages.
3. Local Station + a few of the more powerful distant stations:
   Tuner + 1 H.F. + Det. + Output stages, or
   Tuner + 1 H.F. + Det. + L.F. + Output stages.
4. As in 3, but more distant stations:
   Tuner + 2 H.F. + Det. + Output stages, or
   Tuner + 2 H.F. + Det. + L.F. + Output stages.
5. Universal European receiver:
   Super-heterodyne.
6. For maintenance of quality band-pass tuning and possibly also an L.F. frequency corrector should be looked for.

N.B. For this purpose a station more than 70-80 miles away should be reckoned to be a distant station.

CABINETS.

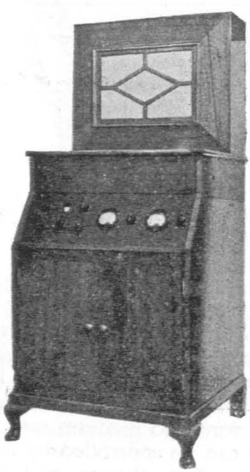

FIG. 23—A radio-gramophone designed by the Technical Staff of *The Gramophone*. Note the unorthodox cabinet.

Cabinet design has altered very little. The cabinet of a year or two ago is still, in the main, the cabinet of to-day. Few attempts are made to get away from the orthodox. Why cannot we have a design in which the speaker is placed well away from the floor and from absorbent carpets etc? Attempts in this direction were made by *The Gramophone* in connection with the Vox battery and A.C. radio-gramophones which were described in April, May and August 1929 issues, and in the November and December 1930 issues, respectively. One of the cabinets is shown in Fig. 23. Notice the position of the speaker, the ease with which tuning and other adjustments can be carried out and the adequate record storage cupboard—large enough to accomodate 160 records. Incidentally this cabinet can be obtained complete or in finished parts ready to glue and screw together from W. J. Bond & Sons, Milton Avenue, Harlesden, N.W.10. One firm specialises in two piece radio-grams, the amplifier and turntable being contained in one cabinet and the speaker in a separate case. From some points of view this is a very desirable arrangement. Another form of radio-gramophone has just been produced in which a large external horn can be used to reproduce records by the ordinary sound-box, or the horn can be utilised as a loud speaker by interposing a moving coil unit in the acoustic system and switching on the radio set contained in the cabinet (*see* Fig. 19). In addition to the tone-arm and sound-box, a pick-up is fitted and thus one has the choice of either radio and the electrical or acoustic reproduction of records, *and* the speaker is high up in the room. In a third form, which again has much to commend it, the receiver and loudspeaker are in one case, commonly in the shape of a large mantelpiece clock, and the turntable unit is separate. In this case the lazy man can change his gramophone records without moving from his chair and still have the sound issuing from a loudspeaker which is placed at a distance and at a reasonable height in the room.

Loud Speakers and Their Position.

This question of the position of the loudspeaker in the room is worthy of much more attention than is commonly given to it. It is specially important with a moving coil loudspeaker or a dynamic loudspeaker, as it is sometimes called, which has a large bass response and considerable power. Not only does the position determine to a large degree whether room resonances are to be set up (and it is to be observed in this connection that the dimensions of an ordinary room are comparable to the wave-lengths of the low notes produced by the speaker so that room resonances are easily produced), but also it has a marked effect on the absorption of notes of different pitch. If the speaker is near the floor, or situated close to heavy furnishings, the reproduction may become muddy and lacking in detail owing to the premature absorption of high notes. On the other hand, heavy furnishings (curtains, plush or velvet upholstery, etc.) are usually an advantage at the end of the room remote from the speaker, since they tend to absorb rather than to reflect the vibrations and in this way minimise room resonance. For a similar reason the position in relation to the windows in the room should be studied since these form efficient vibrating surfaces. It is often found an advantage, too, to have the speaker not far from the fire place; the temperature distribution in the room may have a marked effect. No precise rules can be laid down. In any particular room it is a question of trial and error. But the trial is well worth while in order to avoid the error.

As regards types of loud-speaker, there is now no doubt that the moving coil system has advantages over all the others. For the best quality of reproduction, the large exponential horn speakers with moving coil driving units hold pride of place. Provided the horn is large enough, they have the power and the bass range of all the more usual types together with a delicacy and a nimbleness of high-note response which the others lack. With them one gets the sensation of smoothness combined with definition which makes the ordinary type sound somewhat coarse by comparison. Moreover, the same sort of quality persists for a wide range of volume level as compared with a rather limited range for an ordinary moving coil speaker. But to obtain these advantages the horn must be large (a cut-off well below 100 cycles is required) and the moving coil driving unit must be carefully designed. For ordinary home purposes where spatial limitations are of great importance, the ordinary form of moving coil speaker mounted in a box cabinet or on a fairly large baffle

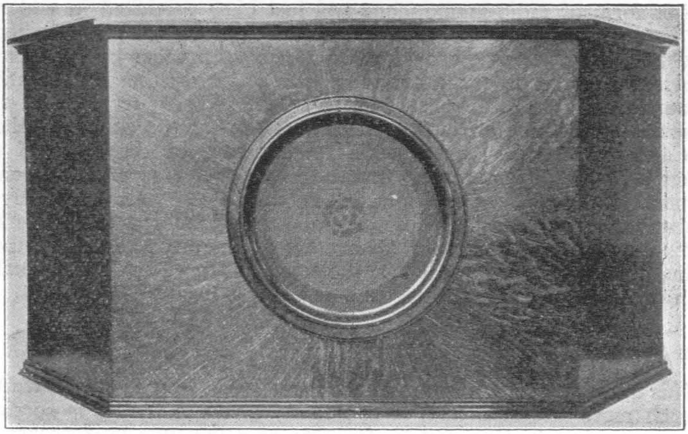

FIG. 24.—A successful form of Loud Speaker baffle cabinet designed by the Technical Staff of *The Gramophone*.

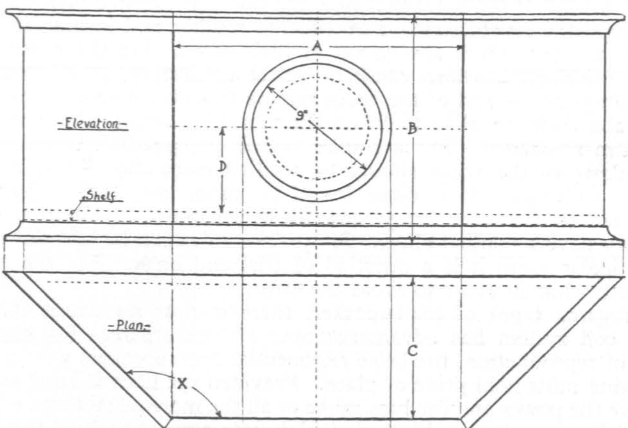

FIG. 25.—Constructional Details of baffle cabinet shown in FIG. 24. A = 20, 22, 24 inches; B = 16, 18, 20 inches; C = 10 to 12 inches; D = to suit speaker centre; X = 120 to 135 degrees.
N.B. The Alternative dimensions are for different sizes of cabinet; thus by using A = 20 inches; B = 16 inches; C = 10 inches the smallest recommended cabinet would be constructed. Not less than ½ inch material should be used.

is more popular. The only type of speaker which gives anything like the same range of response and of power is the Inductor-Dynamic. Small horn loudspeakers have gone into a well deserved oblivion and ordinary "balanced armature" cone loud speakers seem likely to follow suit.

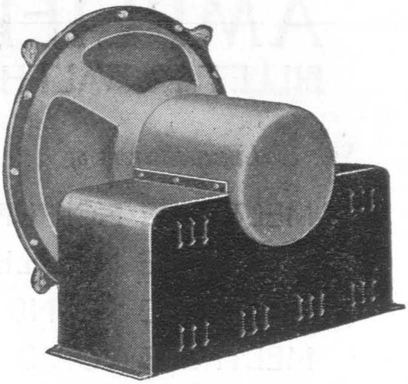

FIG. 26.—The Baker's Selhurst 1932 Super-Power A.C. Moving Coil Speaker. The step-down mains transformer, metal rectifier and electrolytic condenser are incorporated in the speaker base.

It is remarkable what large differences in quality there are between loudspeakers of the same general external design. At one time it was thought that the improved quality secured by the moving coil type was principally due to its freedom from mechanical resonances. Dr. McLachlan's researches, however, have shown that this is not so. It appears to be due to the more or less even distribution of the resonances throughout the scale, as well as to the fact that in this type a large amplitude of motion is possible. This being so, the relative sizes of the various resonances play an important part. Many popular models have a very large resonance just below 100 cycles, and this gives the impression of a good bass response. On analysis, however, the bass is found to be practically confined to a narrow band, definition and detail are lacking, and the ear soon begins to tire of hearing the same note booming out behind everything. Similarly other speakers have a large high note resonance in the octave between 3,000 cycles and 6,000 cycles. This gives a sensation of brilliance or keenness; the strings have more bite in them, the sibilants more definition even to the extent of a hiss and so on. Here again, however, the ear soon begins to get dissatisfied and to demand something less obtrusive. In choosing a loudspeaker therefore (or a complete radio-gramophone), it is important to satisfy oneself that there are no very prominent resonances, as well as that the response goes high and low in the scale. Another point to look out for is a certain spatial effect: close your eyes and see whether you can visualise the spacing of the instruments or whether the sounds all seem to come from the same point in space; notice that the spacing should be 3-dimensional—it should have depth as well as superficial area.

One development of recent years should be noted more particularly. When moving coil loudspeakers were first introduced, an exciting current had to be provided to form an electro-magnet. Ordinary permanent magnets were not strong enough. Recently, however, by the use of cobalt steel and by careful attention to points of design, magnet manufacturers have produced special types for use in connection with moving-coil loudspeakers which have effected marked improvements in sensitivity, range of response and permanency of magnetisation. The better models of electro-magnet speakers are still more efficient in response to low bass and high treble, but for all ordinary purposes the permanent magnet types are now completely satisfactory.

CHAPTER X.

PICK-UPS.

There are still some people who imagine that by fitting a pick-up to the tone-arm of an existing gramophone in place of the sound-box, or by fitting a pick-up which is complete with carrying-arm to the base board of a gramophone, that they will be able to reproduce records electrically through a loud-speaker. This of course, is a complete mistake. Some form of electrical amplification, such as the low-frequency stages of a wireless set, or a special valve amplifier, must be interposed between the pick-up and the loud-speaker. On an electrical reproducer the pick-up is the equivalent of a sound-box in an ordinary gramophone. The needle is mounted in a socket attached to an armature which is pivoted to move in a magnetic field created by a magnet and its associated pole-pieces. When the needle is lowered into the grooves of a record, the musical vibrations are transmitted to the armature which produces electrical vibrations in a coil surrounding it or alternatively in coils disposed on the pole pieces. These are conveyed through the pick-up leads to the grid of the first low frequency valve, and thereafter they are amplified by each successive stage and reproduced in the speaker as music.

For adequate reproduction of records a certain minimum power is required. It is curious that this should be considerably greater than that required for good radio reproduction, but such at present is the case. How far this is due to faults in the pick-up (and it often is) or to faults in recording (and some of it always is) it is not now necessary to inquire. One usually reckons that twice the power-handling capacity is required for records as for radio. That is why in the preceeding pages we have emphasised the necessity for a large power valve in the output stage and the difficulty of using battery operated amplifiers for gramophone reproduction.

When pick-ups were first produced not only was the output relatively small and the range of response short, but record wear was much more pronounced than the good gramophile was accustomed to. It is only quite recently that the various factors governing the performance of a pick-up have come to be properly understood, and even now there are many elements of doubt in the minds of well-informed technicians as well as much misunderstanding generally. Some things, however, can be demonstrated with complete certainty and provided these features are carefully watched a high standard of reproduction can be secured with but small record wear—smaller in fact than that produced by the best gramophones.

So far as the design of the pick-up itself is concerned, very little can be said in a little book of this character. Theoretically a pick-up is somewhat complicated by the fact that mechanical, magnetic and electrical processes are all involved. It may be said, however, that the principal difficulties are concerned with the damping of the armature both to absorb the mechanical vibrations and to counteract the effect of the magnetic field on the mechanical motion. Here we have a different problem from that encountered in a sound-box where the acoustic load can be designed to effect all the damping that is necessary; and further any accidental errors that may occur are here amplified, and may therefore become more prominent in the final result. A good pick-up is thus more expensive to make than a good sound-box and a much more sensitive adjustment is required. Two points should, perhaps, be specially noticed. The first is that a high voltage output in a pick-up, though desirable in that it cheapens the cost of the amplifier necessary to give a certain power output to the speaker, can only be obtained as a rule at the expense of some other desirable feature. This does not mean, of course, that those pick-ups with a low output are necessarily the best—for low output can be caused by a number of undesirable features: weak magnets, heavy damping and so on. But it does mean that if one is concerned to obtain the best quality, a very high output from the pick-up must not be looked for, and one must be prepared to have 3 stages (including the output stage) of amplification to get a power output of more than 2 watts. The second point is that owing to the difficulty of absorbing the mechanical vibrations adequately, the needle is apt to buzz and chatter in the groove. Because a stiffening or slackening of the damping does not remove this, some people have been led to think that the damping has no bearing on the matter. It has. The absorptive properties of a damping system are not solely governed by its stiffness. In the ordinary way if one wishes to absorb mechanical motion with the least reaction on the motive force (the record), one uses a resistance (friction, viscous liquid or any method of converting energy into heat) rather than stiffness. The amount of chatter of the needle in the groove is one indication of the effectiveness of the damping on the armature of a pick-up in absorbing energy. In a well-designed pick-up the damping is very effective, judged by this criterion, and yet the motion of the armature is comparatively free. In these circumstances too, it is found that the pick-up is free from marked resonances and if it happens to have a good high note response (which is not necessarily the case, especially as the attainment of such a result by means of a high-pitched mechanical resonance is ruled out) the surface noise is found to have a soft, crackling quality rather than a coarse sand-papery quality; further the amount of surface noise relative to the high notes reproduced is smaller than one usually finds.

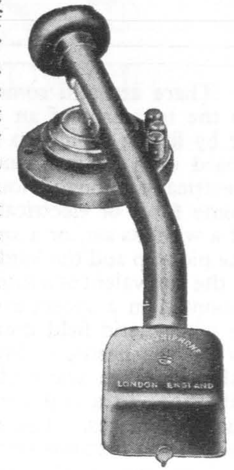

FIG. 27.—The Marconiphone No. 17 pick-up primarily designed for use with steel needles.

As in the ordinary gramophone, the design of the carrying arm and the method of attachment of the pick-up to it are important both from the point of view of reproduction and from that of record wear. A short light arm should be avoided. A light arm often gives rise to a mechanical resonance—or more correctly an anti-resonance since it has the effect of passing vibrations along the arm which should be transmitted through the armature; at such a point, therefore, the electrical output of the pick-up is reduced and a trough appears in the response curve. All carrying arms have such a resonance and to place it very low in the scale is a matter of considerable difficulty. Usually it appears between 100 and 300 cycles, but in some cases it is even higher.

With a short arm good alignment is only secured with difficulty, and then at the expense of other desirable properties. The same principles as regards offset and overlap apply here as in the case of tone-arms.

Generally speaking, it is desirable for these reasons to buy a pick-up already mounted on a carrying arm, rather than to fix one to an ordinary tone-arm. Most commercial pick-up arms are offset but there are still one or two which are straight. These should be avoided, for no matter what the distance between the needle point and back pivot is, or how the arm is set up in relation to the turntable spindle, alignment errors and consequently record wear are bound to be excessive. The overlap tables on page 61 can be used equally well when setting up a pick-up as with a tone-arm and sound-box.

The weight on the record, using steel needles, should not be below 4 oz., nor should it exceed 6 oz. In some commercial pick-ups the weight can be varied by a spring loading device incorporated in the carrying arm; other arms are fitted with a balancing weight at the extreme end to counter the weight of the pick-up head and the fore part of the arm. With non-metallic needles—fibres, Burmese Colours, Electrocolors and Fayotones—this weight can sometimes be increased with advantage to as much as 7½ oz.

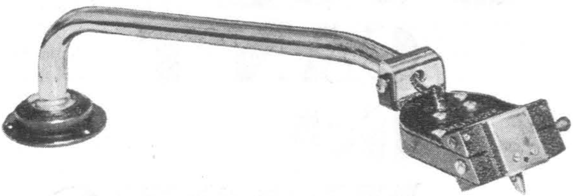

FIG. 28.—The Meltrope pick-up. Note the collet system of gripping the needle. This pick-up can be used with Fibre needles, Burmese Colour needles or with ordinary steel needles.

There are few pick-ups on the market designed for use with fibre needles. Nearly all of them have a needle socket drilled only for steel needles, and to use fibres with these one has to pare the needle down to have a round shank. In most cases, however, the reproduction with fibres in such circumstances is not really satisfactory. For as with sound-boxes it will be found that there is always one type of needle which will suit a particular pick-up best; indeed, pick-ups are definitely more critical of length and type of needle than sound-boxes. There is no particular golden rule for deciding which needle to use and how much to leave protruding from the socket; our old friend, trial and error must decide. Generally speaking, protruding lengths between ¼ and ½ inch are found suitable.

Of the pick-ups designed for fibre needles, with special triangular sockets, one, the Meltrope (shown in Fig. 28), is of the ordinary moving iron type, and has distinguishing features in that both magnetic and mechanical damping are used, and the needle holder is in the form of a split collet which grips the needle without the necessity for a needle screw. In this way, by the use of different collets the pick-up may be made suitable for any type of needle, ferrous or non-ferrous. The other type, the E.M.G., is specially interesting because it is the only successful moving coil pick-up on the market at present (so far as we are aware). It is a somewhat delicate instrument, finely adjusted, and its output is so low that a special transformer has to be used in conjunction with it; so that the total cost (of the whole outfit) is much higher than usual. But the quality is excellent.

Chapter XI.

MISCELLANEOUS HINTS.

Straightening Warped Records.

First of all get two pieces of plate glass about 13 inches square, thoroughly clean and dry them, and finally polish with french chalk. Then hold the warped disc by its edge between the fingers of each hand with the surface of the record at right angles to the palms. With the surface of the record facing the fire, and about 18 inches away from it, slowly rotate the record until the face becomes nicely warm. Reverse it and treat the other side in a like manner, being very careful not to get it too warm. Place the record between the two pieces of plate glass, adding a few large books or a record album on top, and allow to cool. If the record is not absolutely straight when removed repeat the process, this time warming the glass plates also. Thus you will get a slower rate of cooling.

A Suggested Dope for Fibre Needles.

The object of doping fibres is to make the points tougher so that they are less susceptible to breaking down in the heavy passages of a record, and so that the reproduction is cleaner and the volume slightly greater.

Make a saturated solution of Gum Arabic and water and a saturated solution of Potassium Bichromate and water. When the fibres are ready for doping—*not before*—thoroughly mix two parts of the Gum Arabic solution to one part of the Bichromate solution in a dark room and leave the needles in the mixture, also in the dark, for at least fourteen days. Then remove and wash the fibres lightly in water and wrap in a cotton duster to remove surface moisture. Allow the fibres to dry in the sunshine or any artificial ultra-violet light such as that used by draughtsmen for taking blue-prints, or even one of the domestic " sunshine " appliances now on the market. When the needles are absolutely dry clip and use in the ordinary way. But remember the " don'ts."

Don't mix the two solutions until the fibres are ready for doping.

Don't expose the mixture to light.

Don't dry the needles in front of a fire or in an oven.

Alignment and Repositioning a Motor.

When fitting a new or different pattern tone-arm to a gramophone it is nearly always found that to get the best alignment the distance between the back pivot of the original tone-arm and the turntable centre has to be readjusted so as to give the necessary overlap. Since—in most cases—it is impossible to alter the position of the tone-arm, as this must register with the neck of the horn, the only other course open is to reposition the motor. It may be necessary to fit a new motor board in some instances, but the chances of this are fairly remote.

First of all you will require a Wilson Protractor. Then place the turntable with a 12 in. record on the motor board with a small stump of a pencil projecting through the centre hole, point downwards. Place the protractor on the turntable and proceed to test the alignment in the ordinary way (according to instructions printed on the protractor), moving the turntable about until the minimum alignment errors across the record are shown by the protractor. If the new tone-arm is of good length and has a satisfactory amount of offset, it should be possible to set the turntable so that the maximum errors at the inside and outside edges, *i.e.*, at 2 and 6 inches radius, are not more than 3 degrees, and the error at 3½ inches is the same but in the opposite direction. In between there are two places where the error is zero. If these results are not obtainable and a compromise has to be made, it is better to arrange matters so that the error at 2 inches is slightly less than that at 6 inches. When the best position has been found the pencil will show you the point at which to drill the new hole for the motor spindle. It will probably be necessary to drill a new hole in the side of the cabinet for the winding handle and the position for this must be found by careful measurement.

TABLE OF BEST OVERLAPS.

All Dimensions in inches.

OFFSET.	Tone-arm length from back centre to needle point.								
	8	8½	9	9½	10	10½	11	11½	12
2	0	0	0	0	0	0	0	0	0
2¼	·09	·09	·08	·08	·08	·07	·07	·06	·06
2½	·19	·18	·17	·16	·15	·14	·14	·13	·12
2¾	·29	·27	·26	·24	·23	·22	·21	·20	·19
3	·40	·37	·35	·33	·31	·30	·28	·27	·26
3¼	·52	·48	·45	·43	·41	·39	·37	·35	·34
3½	·65	·61	·57	·54	·51	·49	·46	·44	·42
*3¾	·79	·74	·69	·65	·62	·59	·56	·53	·51

*Ideal Offset.

RECORD CLEANING.

Records, as most of you know, are very receptive of dust and dirt. If they are to have a reasonable length of life they must be kept clean. It is not sufficient merely to keep them in envelopes and albums. They should be dusted before and after each playing. But do not rub them too hardly. If you do that, especially with some types of material (*e.g.*, silk, fur, or velvet) you will electrify the surface and cause it to attract dust, much as an amber cigarette holder will if you rub it with a silk handkerchief. The best method is to rub the record quite lightly with a brush or other material which will not create electric charges so readily, and yet which will penetrate right into the grooves.

Cotton cord is admirably suited for the purpose; it does not create electric charges readily and it has a stiff pile which is able to shift those obstinate specks which lodge themselves in awkward corners of the grooves. Cotton cord can be obtained from *The Gramophone*, 10a, Soho Square, London, W.1, price 6d. post free. To make a cleaning pad fasten a piece of the material to a cabinet maker's sand-paper block with drawing pins. It is a refinement to face the block with a thin layer of cotton wool; but this is not really necessary. The drawing pins of course should be pushed through the material into the sides and ends of the block and not into the flat surface. It is important not to allow the cotton cord to get dirty or the cure will become worse than the disease. Cotton cord is easily washed.

"Washing" Records.

One of the disadvantages of fibre and other non-metallic needles is that the debris worn from the needle, particularly after a few breakdowns, will eventually clog the groove. Furthermore, if dust and grit are allowed to remain on the record they will embed themselves in the needle and act as an abrasive. The golden rule is: "keep your records clean." But if by any chance you have allowed them to accumulate fibre debris, etc., the following method of cleaning, though rather tiresome, will prove efficacious. Make a mixture of 2 parts white vinegar and 1 part Three-in-One oil. Shake this to an emulsion, and rub it into the grooves with a clean piece of silk until no liquid apparently remains on the surface. Leave the record for about 10 minutes and then play through with a fibre, repointing several times during the playing. But do not replace the needle in the middle of a loud passage or you will break the point at once. Re-point the needle at each loud passage and start playing again from a place just before the loud passage starts. You may have to play the record a dozen times before the debris is removed, but the results amply repay the trouble taken. After applying the cleaner it is important not to rub the surface again until the record has become dry. Cleaning by actual playing lets the needle cut a track through the clogging matter.

With patience this is a certain cure for fibre clogging and it also enables a record which has been played a fair amount with steel needles to be "broken in" for fibres, though even more patience is required for this.

Some readers who have already tried this method have found it difficult to remove all the oil from the grooves and consequently they are clogged with dried oil. In these circumstances wash the disc in tepid water, using a shaving brush and a soap which produces a good lather. Rinse them with clean tepid water and dry with a clean piece of silk. Afterwards play the record frequently and between each playing rub with cotton cord.

But do not use any kind of cleaning mixture unless it is absolutely necessary.

A Device for Measuring the Weight on the Needle Point.

To measure the weight actually on the needle point when playing a record is quite a simple matter. All you require is a small spring balance reading to 8 ounces, and a flat piece of wood or cork about 3 inches square. To each corner of the latter fasten a piece of linen thread, knotting each together at the other end. Hook this on to the spring balance. To take the weight the needle point is rested exactly in the centre of the piece of wood with the sound-box at the correct angle on the tone-arm. Raise the spring balance so that the wood is clear of the turntable and read off the weight. The stirrup and spring balance arrangement illustrated here is a more elaborate device. It is easy to make, is inexpensive, and can be

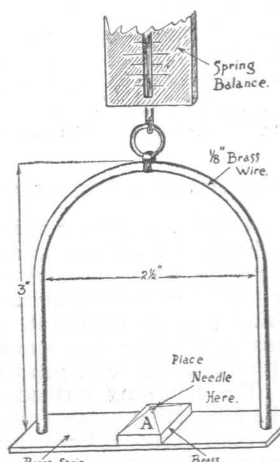

Fig. 29.—A device for measuring the weight on the needle point.

used either with sound-box or pick-up. There is no need to describe it, the illustration gives all the necessary information. It is not essential to fix a needle rest (A) on the strip; a small indentation made in the centre of the brass strip with a centre punch will serve equally well. With this it will be necessary to deduct the weight of the stirrup from the reading taken, or better still, previously set the spring balance at zero with the stirrup in position.

Leaks.

Have you ever had the feeling that of late your gramophone is not giving the results that it used to? Maybe you have. Probably when you bought it you were of the opinion that there was nothing in the world to touch it. The quality was fine and the bass and treble all that could be expected of such an instrument. After a little while you begin to criticise the reproduction; the bass is not what you think it ought to be, or there is distortion here and there. The instrument is probably just as efficient as on the day you bought it. If so, then the gramophone is doing its job: it is teaching you little points about music that otherwise you would never have realised. Thus does your gramophone, and perhaps, musical education begin.

These same effects, however—the suppressed bass and minor distortion—can be due entirely to air leaks in the sound conduit of your instrument. Usually, the nearer the leak to the sound-box the more deleterious the effect. For instance, a $\frac{1}{16}$in. diameter leak near the sound-box would have a worse effect on reproduction that a $\frac{1}{4}$in. diameter leak near the base of the tone-arm and horn. With modern sound-boxes, especially those with the Meltrope type of back-fitting, a leak between tone-arm and sound-box is improbable though possible. If you have any doubts at all, a small rubber ring (an umbrella ring will do) pushed up against the back plate of the sound-box when in position is all that is needed. Leaks in the forward joint of the tone-arm and the joint between the tone-arm and tone-arm base, can be detected by removing the tone-arm, sealing the base end and blowing tobacco smoke through from the sound-box end. If the joints are not air-tight fill them up with vaseline. A leak between the base of the tone-arm and horn can be detected in the same way, but a leak between the base and the baseboard is more difficult to find. To make sure, fit a washer of very thin rubber between the baseboard and the tone-arm base.

Non-Metallic Needles and Difficult Records.

The breaking down of fibres, Burmese Colour and Electrocolor needles on heavy and difficult recordings is a stubborn problem to solve sometimes. In some cases sound-boxes which are totally unsuitable, or stiff tone-arms, or badly levelled machines have been the cause of the failures. Others claiming good alignment, a free tone-arm and a dynamically levelled instrument have still found it impossible to negotiate certain records without having to re-point the needle.

The following method of "lubricating" record is often effective. The lubricating consists of nothing more or less than holding the point of a good quality BB pencil throughout the grooves of the revolving record, first giving the record a good clean with cotton cord or the usual cleaning pad. Many records yield to this treatment first time but the more difficult may need a second coat of graphite before it is possible to play through the side without re-pointing the needle. This method disfigures the disc to a certain extent. A more expedient way is to apply a little Glydola or high grade graphite. But use it sparingly.

RECORD SPEED-STROBOSCOPES.

Make sure of the speed of your turntable by putting a slip of paper on it so as to protrude beyond the edge, laying a record on top and playing the record (begin counting from 0 not 1). Count the revolutions of the strip of paper with your watch in hand. For 78 revolutions per minute, which is the recording speed of most makes of records, the paper should revolve 13 times in ten seconds. Alternatively you can get a mechanical speed tester issued by H.M.V. or Columbia for a few shillings which will save you the trouble.

If you have electric light laid on—*it must be Alternating Current*—by far the best speed tester is the Stroboscopic disc. You can obtain one in ivorine from *The Gramophone,* 10a, Soho Square, London, W.1, price 1/-. One side of the disc is arranged for 80 and the other side for 78 revolutions per minute but it is only suitable for use in connection with a 50 cycle electric supply. In some parts of the country and abroad the supply is of different frequency. The calculation of the number of black and white sectors required for other supplies is a comparatively simple matter. An electric light (A.C.) flashes at twice the frequency of the electric supply. So if the frequency is f per second there are $2f$ flashes per second. Now if we arrange the number n of black spokes on the disc so that when the turntable is making r revolutions per minute one spoke moves exactly to the position of the next spoke in the interval between the flashes, the spokes will appear to be at rest for that speed of revolution. To find the number of black spokes required for any speed therefore, we multiply the frequency of the electric supply by 120, and divide the result by the number of revolutions per minute that we are aiming at. In short, this is the formula :—

$$\text{No. of black spokes, } n = \frac{120 \times \text{Frequency of the supply}}{\text{Speed of record required}} = \frac{120f}{r}$$

e.g. suppose we wish to make a stroboscope suitable for a 60 cycle supply with the turntable revolving at 78 revolutions per minute then using the above formula :

$$\text{No. of black spokes} = \frac{120 \times 60}{78} = \frac{7200}{78} = 92.307$$

So we construct a disc having 92 (nearest whole number) black spokes which of course gives us 92 white spokes also. Therefore the disc must be divided into 184 equal sectors. The following table gives the number of black spokes for various electric supply frequencies :

Frequency of Supply		15	25	33	40	50	60	80	90	100
Speed of Record.	78 r.p.m.	23	38	51	62	77	92	123	139	154
	80 r.p.m.	22	37	50	60	75	90	120	135	150

Never assume, because the speed indicator on your motor points to 78 that the turntable is revolving at 78 revolutions per minute. These indicators are only intended as a rough guide and are rarely correct.

Replacing Motor Springs.

If you have a multiple-spring motor and one spring breaks, do not simply have that one spring replaced. If you do, the other(s) will probably break within a very short time and you will have to have the motor taken apart again. When one spring breaks (provided that it has given good service for a reasonable time) *all* the springs should be replaced; it is expensive to start with but cheaper in the long run.

The Problem of Record Storage.

Here is a system which has proved in practice to be eminently simple, practical, and cheap. It also has the advantage that it can be worked from the first few records up to a collection of any size without involving any reconstruction or rearrangement of the records.

The main idea is that the records are kept in stout manilla envelopes tightly packed on shelves like books, with the open side of the envelope outwards. The envelopes are numbered at the top corner from 1 upwards. The shelves can, of course, be of any capacity, but we have in mind a cabinet designed to hold about 1,000 records, which was made by a jobbing carpenter at a cost of £4. It is constructed of American white wood, stained black, measuring 3 feet wide, 4 feet 8 inches high, 13 inches deep all inside measurements, and holds four rows of records, about 260 in each row. Each shelf is divided by a partition in the centre so that there are in all eight divisions about 18 inches wide and 13 inches high. The back is boarded in to exclude dust, and this, with the partitions, affords a support which is highly desirable in view of the enormous dead-weight to be sustained and the fact that any sagging of the shelves would be fatal. The shelves themselves are ¾ inch thick, and the whole thing is finished off at the top and bottom with a bevelled moulding, the front being covered in by a curtain sliding on a brass rod. No attempt should be made to divide records into classes on the shelves, as this would mean that blank spaces would have to be left in each section for new records, which would defeat one of the main objects of the system. This requires that the records should be packed sufficiently tightly to avoid the possibility of warping and that each new record purchased should without delay be given the next available number and added on at the end of the last section, which is therefore the only one on the shelf which does not fulfil the first condition until it is filled up. The records in it can in the meantime be supported by one or two large books, such as empty record albums.

The classification is all done in the catalogue, which is the key to the contents of the shelves. It may of course be a complicated affair with any number of cross-headings on the lines of the H.M.V. catalogue. Those, however, who are obsessed with other occupations, the approach of old age, or a natural desire to take the line of least resistance, can be content with something much less elaborate. Take a small loose-leaf book, divide this into a few simple headings, such as Orchestral, Chamber Music, Violin Solos, Piano Solos, Vocalists, etc. The Orchestral section can be subdivided into Composers arranged alphabetically thus:

Orchestral.

Brahms: Weingartner. Columbia.
Symphony No. 1 C Minor. Number 68.

The remaining sections are perhaps best subdivided under the various artists or combinations, also arranged alphabetically.

The essential point is that against each record must appear the number indicating its position on the shelf.

When all your records are stacked up and listed, the procedure is as follows:

Suppose you wish to play the Brahms Symphony No. 1. Look it up in the catalogue under Orchestral: Brahms Symphony No. 1. You find it opposite the number 68. Go to the shelf, run your finger along until you reach number 68, insert your finger and thumb (an easy matter as the records being round and the envelopes square the top corners are all empty) pull out the envelope about half-way and take out the record, leaving the envelope sticking half out of the shelf—simply crying aloud to you to replace the record when you have done with it.

Do not, of course, stack 10 inch records side by side with 12 inch; a separate shelf should be reserved for 10 inch records, which should be numbered from 1 upwards in the same way as the 12 inch, and can be distinguished in the catalogue by a letter prefixed to their numbers.

The above is all that is absolutely necessary, but various embellishments can be added if desired. For instance, cardboard squares can be inserted at specified intervals, say every 10, 50 or 100 records, to assist one in following the run of the numbers; or labels can be pasted on the shelves over the records giving a rough idea of what numbers they contain. The numbers can either be written in ink on the top corner of the envelopes, stamped with an office numbering stamp, or sheets of adhesive numbers printed on perforated squares like sheets of postage stamps, can be obtained at many commercial stationers'. The working procedure can also be varied to suit special requirements, such as the making up of an evening's programme, the records for which can be taken from the shelves in their envelopes; the numbers on them will enable the envelopes to be readily returned to their proper places when the evening is over. If single movements of a symphony or quartet are purchased separately, they can be brought together on the shelves by giving them all the same number with the addition of letters a, b, c, etc.

MATCHING A SPEAKER TO AN AMPLIFIER.

Undistorted Output.

In several places in this little book the maximum undistorted (A.C.) output of the output stage of a receiver has been mentioned. It should be explained, however, that this phrase does not quite accurately describe the true position. There are two points of doubt which have been left undisclosed. The first is, what we mean by *undistorted;* the second is in what conditions the maximum output as thus defined can be secured.

As regards the first point, it should be remarked that a certain amount of distortion is inevitable in every amplifier, in the sense that the amplifier will not magnify all notes of every frequency from zero to infinity in the same proportion, and that it may introduce some notes which were not present in the original. Usually these latter are harmonics of the originals (*i.e.*, have frequencies of twice, three times, four times and so on of the original frequencies); at any rate, they always are in a well designed amplifier. It should therefore be noted that the term "undistorted power output" of the last stage of an amplifier has no reference at all to the range of frequency with which the amplifier will deal faithfully, though there is no difficulty in constructing a design which will cover from about 30 cycles per second (3 octaves below middle C) to about 10,000 cycles per second ($4\frac{1}{2}$ octaves above middle C). Nor does the phrase mean that harmonic distortion is entirely absent. All it really means is that so much power output can be secured before the harmonic distortion comes above a certain level. What the level is is also a matter of some doubt; some people use one standard while others are more or less stringent. Obviously, it does not much matter how much harmonic distortion is allowed so long as it is not audible. The explanation of the difference of opinion lies simply in the doubt that exists as to when harmonic distortion becomes audible; and also, perhaps, to the fact that the commercial valve manufacturer naturally wishes to put his "maximum undistorted output" at as high a figure as possible!

The majority of technical people, however, seem to agree that the standard should be fixed at the power level which is produced when not more than 5% of second harmonic is present. Usually nothing is said about third harmonic, though this is low as a rule in the standard condition just mentioned. Most pentodes, however, behave differently, for often the third harmonic is fairly strongly produced by a pentode; this is not universally the case, but the exceptions seem to be few at present.

It should also be noted that when two output valves are arranged according to the system known as push-pull, the second, fourth, and other harmonics of even order are largely cancelled out so that on the basis generally agreed upon more than twice the output given by a single output valve might be expected in such circumstances. Unfortunately the third and other odd harmonics do not cancel out so that it is wise to be on the safe side and reckon on double the output only.

It will be appreciated from the foregoing explanation that the term "maximum undistorted output" must at present be understood to be only a rough and ready guide to the conditions in which reasonably good reproduction can be obtained at respectable volume. The usual trend of events in any science is for more accurate criteria to be built up gradually from more or less approximate guides of this sort. So we may hope that in due time a development of this kind will take place here also.

Speaker Impedance.

The power which the output stage of a receiver can deliver within a specified limit of distortion depends not only on the type and arrangement of valve used but also on the type of load into which it is working in its anode circuit. A purely resistive load (that is, one which contains no inductance or capacity elements) is best. In a wireless set the load is the loudspeaker and all loudspeakers so far invented provide loads which are by no means entirely resistive. The nearest to the ideal in this respect is the large horn loudspeaker which has a moving coil driving unit; that is very nearly resistive throughout its range over which the horn operates effectively (see p. 18), but it ceases to be so near the resonance points. The next best is the ordinary moving coil speaker fitted to a large, thick baffle; that is at any rate one reason, if not the principal reason, for the success of this type. Here again, then, we have to compromise. What are we to take as the load imposed by the speaker? In practice, it is found that good results are secured if the impedance of the speaker at some low frequency within its range—say 200 cycles—is taken as reference.

Usually the loud speaker impedance is given by the makers. In the case of moving coil speakers it usually lies between 1.5 and 2 times the D.C. resistance of the speech coil: nearer the former figure for low-impedance coils and the latter for high impedance coils.

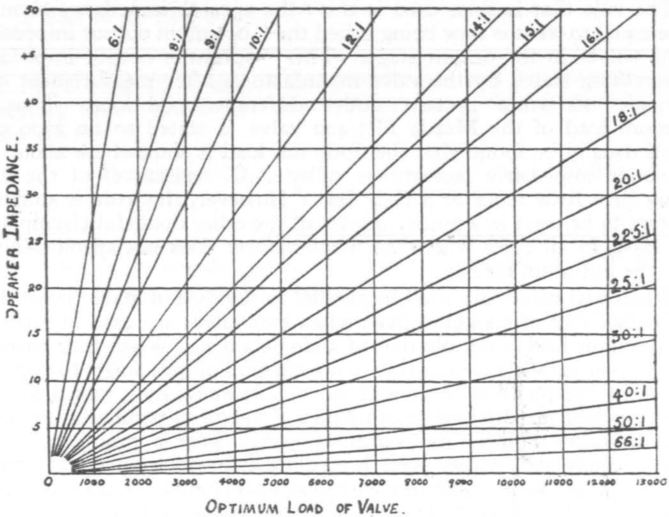

FIG. 30.—Graphs for determining ratio of matching transformer for Low Impedance speakers.

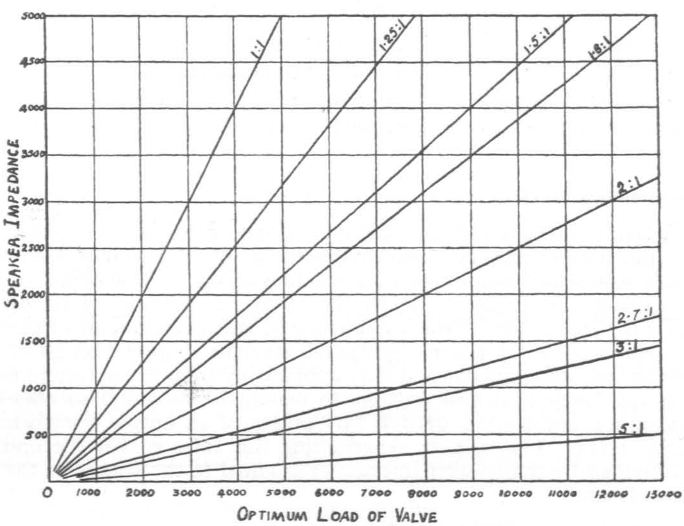

FIG. 31.—Graphs for determining ratio of matching transformer for High Impedance Speakers.

OPTIMUM LOAD.

The rule that is then used is this: the speaker impedance should be made equal to what is now being called the "optimum output impedance" of the valves in the output stage. This "optimum output impedance" is something stated by the valve manufacturer after measurement of the harmonic distortion present under different conditions. Thus, the optimum load of the Mazda PP5/400 valve is stated to be 2700 ohms. It will usually be found that the optimum load is somewhere about twice the anode impedance (sometimes called A.C. resistance) of the valve; it may be a little more or a little less. However, this rule is sufficiently accurate to be used as a guide, amidst all the other doubtful circumstances that exist, in all cases where the manufacturer does not specifically state what the optimum load is.

When two valves are used in parallel in the output stage the optimum load is half that of a single valve; when two valves are used in push-pull, the optimum load is double that of a single valve. When four valves are used, two in parallel on each side of a push-pull output stage, the optimum load is the same as that of a single valve. At one time it was the practice in large power installations to put banks of valves in parallel in the output stage so as to multiply the output power. Such a practice, however, is never really satisfactory since it is difficult to obtain a set of valves of the same type with absolutely identical characteristics and the position when valves of different characteristics are operated in parallel becomes so complicated as almost to defy analysis.

The following table therefore gives the approximate value of the optimum load in the conditions usually met with in practice:—

APPROXIMATE VALUE OF OPTIMUM LOAD.

Single valve: Twice the valve impedance.
Two valves in parallel: Single valve impedance.
Two valves in push-pull: Four times the valve impedance.
Four valves in push-pull, parallel: Twice the valve impedance.

TRANSFORMER RATIO.

When the speaker impedance is approximately the same as the optimum load, the speaker may be connected to the amplifier by what is known as a choke-condenser output, or by a 1:1 transformer. The object of these arrangements is simply to isolate the electrical windings of the speaker from any direct current which is passing in the anode circuit of the valve and only to allow the alternating speech currents to pass through it. But when the speaker impedance differs appreciably from the optimum load of the output stage it is still possible to match the two, and so obtain the "maximum undistorted output," by means of an output transformer of suitable ratio. The rule for determining this ratio is that the optimum load divided by the speaker impedance is equal to the square of the ratio required; or,

$$\text{Ratio} = \sqrt{\frac{\text{Optimum load}}{\text{speaker impedance}}}$$

Thus for a 1932 Marconi PX4 valve, whose anode impedance is 830 ohms and a speaker of impedance 7 ohms the ratio works out to be

$$\sqrt{\frac{2 \times 830}{7}} = \sqrt{237} = 15.4.$$

So a 15 : 1 or a 16 : 1 step down transformer will be necessary as the connecting link. Similiarly, if two PX.4's in push-pull were used, we should get :—

$$\text{Required ratio} = \sqrt{\frac{4 \times 830}{7}} = \sqrt{474} = 21.8$$

So a 21 : 1 or 22 : 1 ratio would be suitable. A corresponding calculation for two PX4's in parallel gives 11 : 1 as the suitable ratio in this case (Note that it is always half the push-pull ratio).

Graphical Representation.

The graphs on page 68 enable one to read off the value of transformer ratio required without laborious calculation. All that one need remember is the approximate rule for finding the optimum load given earlier. Thus, taking the case of a Mazda AC.Pen valve (optimum load 9000 ohms) and a 15 ohm speaker we look along the horizontal line corresponding to 15 ohms until we come to the vertical line corresponding to 9000 ohms ; we find that they cut at a point close to the slanting line marked 25 : 1. This then is the transformer ratio required.

Connecting more than one Speaker.

To obtain proper matching in cases where more than one speaker is connected to an amplifier may be a matter of some difficulty. It is in fact far too complicated a matter to discuss in detail in this book when the speakers happen to have different impedances. In any case, the best results are likely to be obtained if the speakers are alike, in which case the impedance of two speakers in series is twice the single impedance, while that of two in parallel is half the single impedance. In commercial practice even this distinction is commonly neglected. One often finds receivers fitted with sockets or terminals for the connection of an auxiliary speaker ; sometimes, these sockets are simply connected internally to the secondary of the output (matching) transformer, in which case the connection of the second speaker will be in parallel with the one already coupled to the receiver and will upset any matching balance already obtained. Another arrangement which is adopted by some manufacturers is to connect the sockets to the primary of the output transformer (*i.e.*, directly into the anode circuit of the valve) and in this case the external speaker has to be connected through its own matching transformer. A point which is worth watching in such a case is this :—If the auxiliary speaker is to be used some distance away from the receiver it is better to put the step-down matching transformer close to the receiver and not to the speaker. Not only may this avoid the carrying of high tension currents through long leads about the house, but also the fact that the leads are in a low impedance circuit (*i.e.*, the speaker circuit) and not in the comparatively high impedance valve circuit, causes the self capacity of the wiring to have less effect on the output and in this way the loss of high notes may be reduced to a minimum.

EXPONENTIAL HORN TABLE.

(All dimensions in inches).

Length along Axis.	DIAMETER.		
	Cut-off 128 cycles.	Cut-off 90 cycles.	Cut-off 64 cycles.
0	·5	·5	·5
4	·64	·60	·56
8	·8	·70	·64
12	1·02	·84	·72
16	1·30	·98	·8
20	1·64	1·18	·9
24	2·08	1·40	1·02
28	2·64	1·64	1·14
32	3·34	1·96	1·30
36	4·24	2·34	1·46
40	5·36	2·76	1·64
44	6·80	3·30	1·84
48	8·62	3·92	2·08
52	10·92	4·64	2·34
56	13·86	5·52	2·64
60	17·56	6·54	2·98
64	22·26	7·76	3·34
68	28·22	9·20	3·76
72	35·78	10·94	4·24
76	45·36	12·98	4·76
80	57·52	15·40	5·36
84	72·92	18·28	6·04
88	—	21·70	6·80
92	—	25·74	7·66
96	—	30·56	8·62
100	—	36·26	9·70
104	—	43·04	10·92
108	—	51·08	12·30
112	—	60·62	13·86
116	—	71·94	15·60
120	—	85·38	17·56
124	—	—	19·78
128	—	—	22·26
132	—	—	25·06
136	—	—	28·22
140	—	—	31·78
144	—	—	35·78
148	—	—	40·30
152	—	—	45·36
156	—	—	51·08
160	—	—	57·52

APPENDIX I.

DEFECTS IN GRAMOPHONE RECORDS.

BY WILLIAM D. OWEN AND H. COURTNEY BRYSON.

Reprinted from *The Gramophone,* December, 1931 and January, 1932.

There is a story told of a man with an artistic temperament but defective vision who, in the twilight of his days, was prevailed upon to consult an eminent oculist regarding his failing eyesight. The latter, with consummate skill, prescribed lenses that corrected the astigmatism and compensated for the myopia, with the result that the patient's sight was restored to normal.

At first he was much intrigued by the visual precision with which he was now endowed. He saw the shape of the twigs outlined against the sky. He saw the delicate colourings on the butterfly's wing, and the way the rosebud expanded to the summer sun. But he saw also much dirt and dust that had formerly escaped his notice. He saw, too, in people and things, imperfections previously masked by a kindly mist that had intervened and mellowed his outlook. Much that had been picturesque was now disconcertingly squalid. There was a difficulty in getting away from stark details which would obtrude and rob him of the complete detachment with which he was wont to make his observations. There were times, in fact, when he doubted whether the restoration of his sight was really a boon to one who had spent so long in acquiring a new set of values for those impressions he received through the medium of his eyes.

Need the anology be pushed further? Is it not apparent that many of the time-honoured contributors to this journal (*The Gramophone*) are in much the same position to-day in their reaction to scientifically designed sound reproducers as the old artist was in another connection? How else can it be explained that preferences are occasionally expressed for admittedly imperfect devices and that our old timers frequently sigh for the days that are gone? Parenthetically, it might be remarked that there is no law against their using an ancient instrument with pre-electric records if they wish to demonstrate their sincerity.

The adoption of improved reproducers by the authors in 1926 showed the necessity for an entire re-valuation of the merit of recorded music. The relentless precision and increased resolving power of a normal* reproducer reveals imperfections that might be of little consequence were the reproducing medium less faithful. Let us warn the unwary partisan that this is no argument in favour of old-time standards on artistic grounds. Any desired form of " artistic " modification can be applied, at will, in any degree, by those acquainted with fundamental principles. There is neither magic nor merit in this. It is the simple application of known laws to meet the varying demands of individual taste.

Whatever might be one's personal views on the subject of aesthetics, all are agreed that electrical reproduction has made more exacting demands

*The term " normal " is used here to designate an installation in which all components are functioning correctly. The colloquial term would be " perfect " though one cannot get perfect results from an assembly of imperfect components, but one can get either normal or sub-normal results.

on the technique of recording. Records that thrilled us in the past fall miserably below the standards of the present. Imperfections in records have never been tolerated by the really serious gramophile, and are, more than ever, to be avoided now that reproducers can be made to radiate everything but the label. Fortunately the moulder's art has been developed to a wonderful degree of perfection by the great recording companies, and a vigilant inspection department usually safeguards the customer against faulty specimens. Nevertheless, imperfect records are occasionally handed over the counter to unsuspecting purchasers, even now. Indeed, this article was originally inspired by the fact that one of the authors recently failed to find more than one "perfect" record in a batch of thirteen purchased through the ordinary channels of commerce at one of the large West End stores, the majority of the defects lying well beyond the control of the retailer.

It would be as well, perhaps, before considering the types of defect to which this article refers, to deal briefly with two factors that have caused some dissatisfaction. Many a record is hopelessly spoiled, in the estimation of discriminating users, by inartistic presentation of the subject matter.

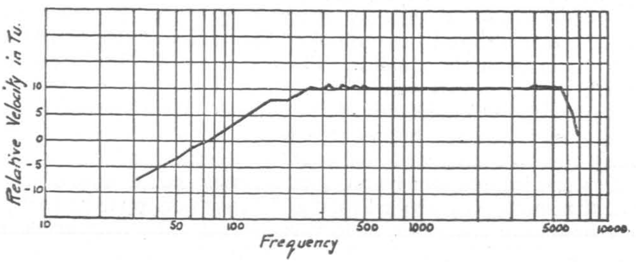

FIG. 32.—Typical Frequency Characteristic of a commercial recorder.

For the purpose of this survey the artistic element is entirely excluded, neither of the authors being qualified to cross swords with W. R. Anderson or Herman Klein on the subject of inartistic expression. Other records are condemned because of what is wrongly called "over-amplification", in regard to which the authors feel no such reticence because "over-amplification" is a myth. There is a commendable tendency to produce louder records nowadays because they reproduce with a larger music-to-scratch ratio. This must be encouraged and reproducers that cannot be adapted to them should be regarded as obsolescent. No trouble from this cause is experienced with electrical reproducers.

The defects dealt with are all due to preventable causes associated with production. Some occur during the process of recording, either in the studio or recording room: others in the course of that group of processes involved in making the stamper or mould. But the majority occur at some stage of the moulding process. They may be summarised as shown in Table 1, the purport of which will be lost, to some extent, by those who have no knowledge of the process of manufacture. Hence, for the sake of completeness a brief description of the process precedes the discussion of the defects enumerated.

TABLE I.

SUMMARY OF RECORD DEFECTS.

PROCESS.	STAGE.	DEFECT.
I. Studio	(*a*) Sound source (*b*) Microphone (*c*) Amplifier	1. Blasting 2. Bass cut-off
II. Recorder ..	(*d*) Electro-Magnetic recording stylus (*e*) Lathe (*f*) Wax blank	3. Granulation 4. Twinning 5. Groove-wall break-down 6. Pattern weaving 7. Piano whine
III. Stamper Production	(*g*) Graphiting and Electro-plating (*h*) Matrices (*j*) Stampers or moulds	8. Dents 9. Pimples 10. Lack of definition
IV. Moulding ..	(*k*) Materials (*l*) Processes	11. Hot and cold pressing 12. Abrasive surface 13. Occlusions 14. Blisters 15. Pull-outs 16. Swingers 17. Noisy surface 18. Uneven thickness 19. Label errors
V. Storage	(*m*) Internal stresses (*n*) External influences	20. Cracks and crevices 21. Buckling

RECORD MANUFACTURE.

The microphone used in modern recording practice is a relatively insensitive device—a defect that is offset by its faithful response characteristics. An amplifier has therefore to be interposed between the microphone and the electro-magnetically controlled cutting tool. This amplifier is designed to cut off the bass, in accord with a recording policy already described (1), so as to give an over-all response characteristic as shown in Figure 32 which has the authority of the Bell Telephone Laboratories (2) where much of the recent development work has been carried out.

A precision lathe, with a heavy horizontal face-plate running at a uniform rate of 78 r.p.m. presents the upper surface of a polished wax blank to the cutting tool (Figure 33) which traverses the record radially in such a manner as to trace an Archimedean spiral having about one hundred convolutions to the inch. The control exercised by the microphone equipment manifests itself in a lateral displacement of the spiral on both sides of the mean position. The amplitude and extent of these lateral displacements are governed by the intensity and frequency of the original sound.

The wax blank is dusted with the finest graphite procurable in order to render it electrically conductive. This operation demands much skill and experience, for the success of all subsequent operations, as well as the lustre of the finished record, depends upon obtaining a brilliant and even film.

The wax is then immersed in an electro-plating bath and a copper "master" deposited thereon by electro-deposition. This "master" is negative of the original wax, the original grooves now being represented by ridges on the surface. From this, by an exactly similar electro-plating process, a copper "mother" is produced, identical with the original but in copper instead of wax. It is from the "mother" that the metal stampers or moulds are made by a repetition of the electro-deposition process, these stampers having their surface plated with nickel or chromium in order that they may stand up better to erosion. The rigidity is increased by backing up the thin shell with an $\frac{1}{8}$in. copper disc.

Two such stampers are mounted on the top and bottom platens of an hydraulic press of special construction and are closed on to a thermo-plastic compound which emerges from the press as the record of commerce.

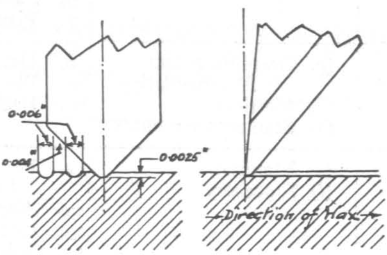

FIG. 33.—Details of the Stylus Point of the Recorder. Left: a radial section through wax; Right: A section looking from the Stylus Point to the centre of the disc.

A full description of the process, showing the presses used and other technical details, has been published in the technical literature (3).

DEFECTS IN RECORDS.

The following consideration of the faults summarised in Table I is not in any sense exhaustive; nor is it critical. In fact the authors are prompted, at this point, to say a few words about the vigorous system of examination adopted in the large gramophone factories in order to prevent faulty records passing out. Every, say, 20th record produced in the press is taken and tested visually and aurally and if any defect is found the previous 19 are played over till the faulty one (if it were a stamper fault) is discovered. An ordinary person could examine dozens of rejected records in a gramophone factory without discovering the reasons for their rejection, so minute are the faults. Nevertheless defective pressings do get through as the following statement will show.

1.—*Blasting* is a form of distortion due to the limitations of a type of microphone seldom used nowadays. It affects all sounds exceeding a certain energy-level, such as those produced by percussive instruments, particularly the xylophone. Ejaculations and stressed words in speech are affected, as well as those components of the spoken word known as "explosives", when the particular type of microphone referred to is operated too near to its upper limit—as it generally is in an endeavour to keep down background noise. It was manifest throughout the whole of the broadcast speech with which Mr. Ramsay MacDonald opened the election campaign in October, speaking from a private room at Covent

(1), (2), (3), etc.—See List of References at End.

Garden Opera House. Blasting is rarely allowed to pass in a normal recording but occasionally has to be overlooked in cinema news and topical items which cannot be repeated. This defect does not lend itself to illustration, but a good example (British Phototone record No. 3934) has been deposited with the Editor. There is more than a suspicion of blasting in Columbia 4354* but this is accentuated because it takes a first-class instrument to do justice to this record. With electrical reproducers overloading or under-biasing may produce effects that might be confused with blasting.

2. *Bass Cut-off* is described as being intentionally introduced in accord with a definite recording policy. Very low sounds, having a frequency below 30 cycles per second, are completely excluded. From 250 cycles to 30 cycles the cut-off declines as shown in Figure 32. This is because to record them in their correct proportion requires a wider groove-spacing than is economically permissible, owing to the reduction in playing-time that it would involve.

Incidentally it appears that recording companies take steps to restore the balance between treble and bass (at least to some extent) by suitably disposing the members of the orchestra in relation to the microphone and by augmenting the bass. Makers of gramophones actually introduce

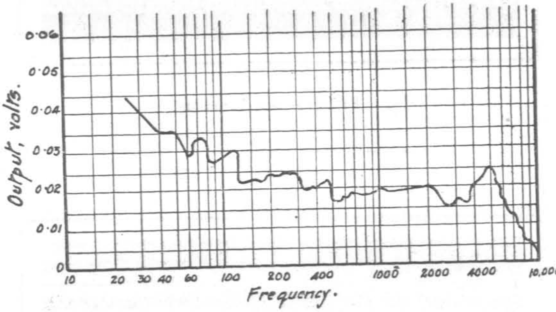

FIG. 34.—Frequency Characteristic of Needle Armature Pick-up as used by the B.B.C.

resonance into their instruments in order to "bring out the bass". Electrical reproducers can be designed to compensate for the cut-off; in fact most pick-ups are given a rising inflexion in the bass as shown in Figure 34. Dr. McLachlan, whose name is well known in connection with the development of moving coil loud speakers, has patented (4) an electric filter-network which, when interposed between pick-up and the amplifier, compensates exactly for the intentional bass cut-off. This extremely ingenious device has already been discussed in these columns (*The Gramophone*) by Mr. P. Wilson (5).

3. *Granulation.*—If the wax blank has been kept in stock too long, or if its constitution is not exactly correct, the structure becomes granular and, as the surface of the record is a faithful reproduction of that of the wax, this micro-unevenness of surface is imparted to the record and leads to excessive noise. A good example of this defect was provided recently among the records produced by a private recording studio in the West End.

4. *Twinning* is a result of the faulty operation of the traversing gear carrying the wax blank when being recorded upon by the cutting tool.

*Frank Mullins (Tenor)—" On with the Motley " (Pagliacci).

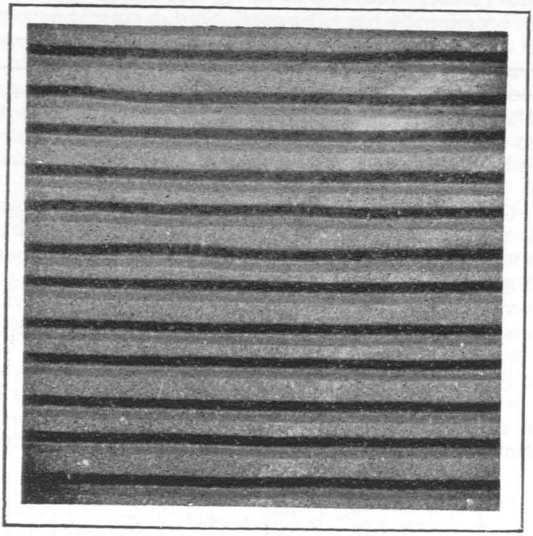

FIG. 35.—See *Twinning*.

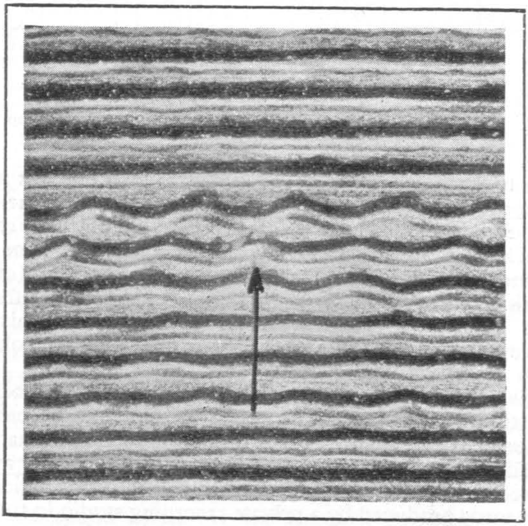

FIG. 36.—See *Groove-Wall breakdown*.

The grooves, instead of being uniformly spaced about 0.01 in. apart, are in pairs slightly less than 0·01 in. apart, the pairs being separated by a correspondingly greater distance as shown in Figure 35. Presumably the friction on the guides is excessive, causing a portion of the carriage to hold back, thus flexing the structure. The energy stored up in this manner supplements the force operating at the point of retardation, and is periodically expended in overcoming the friction. The rate at which the table carrying the wax moves along under the cutting stylus is thus non-uniform. This variation of the speed of translation of the wax has, of course, nothing to do with its rate of rotation. The explanation given here is confirmed by the fact that in one case where the trouble was experienced acutely, it was overcome, after every expedient had been tried without success (including dismantling and rebuilding the recording machine), by the substitution of a lubricating oil having a different viscosity from that recommended by the makers of the machine. Several cases of twin grooving have been found among Worldecho records, one of which is shown in Figure 35. The defect is of little consequence in itself but may lead to a breakdown of the partition between two contiguous grooves for reasons which will be explained later.

5. *Groove-wall Breakdown* (also termed cut-over) may be a constant nightmare to the recording engineer, but is seldom allowed to worry anybody else. A little exercise in simple arithmetic shows the possibilities in this direction. The width of the groove is in the region of 0.006 in. (six thousandths of an inch) and the spacing is 0·01 in., leaving 0.004 in. between contiguous grooves for the lateral displacement to operate in as shown in Figure 36. Obviously a displacement of 0.002 in. in opposite directions is sufficient to cause two adjacent grooves to run together. Therefore the maximum possible displacement must be kept within this limit.

6. *Pattern-weaving* occurs when extraneous vibration causes a vertical oscillation of the cutting tool. In these circumstances the depth of the

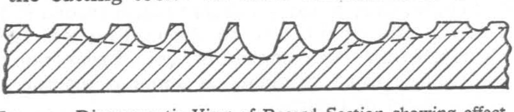

FIG. 37.—Diagrammatic View of Record Section showing effect of vertical oscillation. (Exaggerated).

groove varies in a periodic fashion, which naturally bears some time relation to other periodic factors, such as the rotation of the wax at 78 r.p.m. The consequence is that these two factors, working together, produce a " watered silk " effect which shows up well in reflected light but does not reproduce well in half-tone. These vertical vibrations produce variations in the depth and width of the groove as shown in Figure 37. Now since the reproducing point (needle) possesses a different shape from the recording stylus, especially after the former has become worn so that it has a sort of chisel edge with sharp shoulders, when it drops down into a deeper groove these edges tend to cut into the track and thus reduce the life of the record as well as mar the quality of the reproduction.

7. *Piano Whine* is a term coined to describe that curiously irritating falling off in pitch of sustained notes that characterises all but the most recent piano recordings. Fortunately it is fast disappearing, although one can never be certain that it will not crop up again in the next batch of piano records, irrespective of origin or cost. This suggests that the actual cause is unknown to the recording engineer—as indeed it is to the authors.

As some gramophiles are able to cultivate a tolerance for it, even to the extent of being unaware of its existence (see recent article (6) by Rachmaninoff), the following remarks (7) by a member of the reviewing staff may be of interest :—

> "Before writing in detail on the piano records of this month, I want to make it clear to readers of this column that, in my opinion, the standard of recording piano music is not a very satisfactory one, due, no doubt, to the fact that the piano tone never is a lasting tone, but a pizzicato followed by a decrescendo, the recording whereof has met with greater difficulties than is the case with almost any other instrument. There is so much discoloration and unsteadiness of tone, so much "pang" or "meowing" in the resonance, that the trained ear has the greatest pain in translating these sounds into the familiar language of the piano. I therefore want it to be understood that, as a musician, I form my opinion on piano records in accepting the standard as it is without agreeing to it. The fine exceptions which now and again occur give us great hopes that the engineers ultimately will succeed in their uphill task of improvement."

With a view of stimulating a discussion upon this important subject, through the medium of the Correspondence columns, some speculations are here set down for what they are worth.

(*a*) The pitch of sustained notes occasionally appears to fall off, *i.e.*, the frequency is less at the end of the note than at the beginning.

(*b*) The reproducer has nothing to do with this phenomenon. This applies to both acoustical and electrical instruments. The trouble is on the record and will be reproduced by all machines, good and bad alike. Conversely, a piano record that does not manifest this defect cannot be made to do so by mal-adjustment of the reproducer.

(*c*) The phenomenon is never present in straight radio broadcast, but comes over when a suitable piano record is broadcast.

(*d*) The reaction of the wax on the cutting tool is negligible and the electro-magnetic control is beyond suspicion ; consequently the trouble must originate at some point subsequent to this in the chain of events.

(*e*) A sustained note, especially when it has appreciable amplitude, increases the distance the cutting tool has to travel in a given time (because of the excursions it has to make on either side of the mean line). Consequently more energy is required to drive the wax past the tool. In which case—

(i) The peripheral velocity of the face plate of the recording machine may be reduced. This is extremely improbable owing to the massive construction of the machine and the precautions taken to ensure even speed of rotation.

(ii) The wax may slip on the face plate. This again is improbable.

(iii) The wax blank, being stressed in torsion, may strain—*i.e.*, the upper face (or part of it) may twist relative to the lower face.

8. *Minute Dents* or depressions on the surface of a record, affecting two or three grooves, are usually due to the presence of small lumps of solder or other foreign matter between the copper electro and the copper base on which it is mounted. Air-locks are of rarer occurrence. The trouble is usually caused by carelessness in the backing operation, though

the word carelessness can scarcely be applied to the personnel habitually engaged on this highly-skilled and delicate process. Sometimes these pimples on the stamper do not become apparent till it has been set up in the press and a number of records run off. In this case a series of defective records are produced, each one of which is a little worse than its predecessor. Another sort of depression, usually larger and shallower than the foregoing, is caused by variation in the thickness of the stamper or by faulty bedding of the ring which holds the stamper down, or by stripped threads on the set screws holding the ring, any of which will allow the moulding stock to be forced into the gap between the holding-down ring and the stamper, in which case it gets right under the latter. The presence of material between the stamper and the die, even though the former is over $\frac{1}{8}$in. thick, quickly becomes apparent on the surface and leads to faulty records.

9. *Pimples* are the inverse of the above and may be due to a variety of causes. A piece of bad stock or impurity in the stock will often cause a slight dent to be made in the stamper which is reproduced as a pimple in subsequent records. When such a pimple hits the needle the sound-box is jerked upwards and falls again on to the record on the remote side, and this effect is cumulative unless the pimple is worn down. The noise produced by a pimple is similar to that produced by a dent. Imperfect mixing or grinding of the stock or impurities in it may also give rise to pimples.

10. *Lack of Definition* may be caused by erosion of the metal face of the stamper, due for example to too many impressions having been made therefrom. Upwards of 2,000 records can be produced from a good stamper before any change is discernible. Besides erosion, actual bending of the groove walls takes place, especially at the outer edges where the pressure tends to build up and where, owing to the larger curvature, the wall is not so resistant to lateral pressures. Stampers in this condition, with some of the walls in an almost uncut state, naturally produce a high percentage of pull-out records (see 15 in summary). Such stampers also give records with increased scratch reproduction as the needle does not fit the groove but wears it down on one side only and in some cases tears up the track.

11. *Hot and Cold Pressings*, too, give rise to records which lack definition, especially in the second case, when the die is not hot enough to flux the material sufficiently, so that the record is not properly formed. In this case actual distortion sometimes occurs in the reproduction. On the other hand, if the die is too hot, the record emerges with a sort of wavy sheen on the surface.

If the stock when transferred from the hot plate to the die is too cold, the record appears with irregular brownish stains on the surface. The temperature of ejection is also important. If the record is cooled too much under pressure, it is apt to crack, due to internal stresses on ejection (cf. No. 20).

These faults, though not uncommon in a factory where the presses are not automatically controlled, are so easily detected by the eye that it is rare for records bearing these types of defect to reach the consumer.

12. *Abrasive Surface.*—A school of thought exists which maintains that it is better for the record to wear down the needle point than for the latter to wear the record. Let us consider the consequences when this view is pushed to extremes. The area of contact of a needle resting in the bottom of a groove at the beginning of a record is presumably practically circular and the pressure is very high—many tons per square inch. By virtue of these two facts the needle is able to follow the highly convoluted

sinuosities of a high frequency note, aided as it is by length of the wave of the note on the record due to the greater speed at the periphery. Now when the needle begins to reach the end of a very abrasive record the area of contact is much larger, due to erosion and is no longer circular but oval. The pressure therefore has decreased to a few tons per square inch. The wave length on the record of a note of similar (high) frequency to one at the beginning has progressively decreased, due to decreased linear speed, till at the centre it is only about one-third of what it was at the commencement of a 10-in. record ; in other words, the sinousities are packed about three times as tightly together. If the shape of the wave were a sine curve of say 5000 cycles, the needle, because its flattened point is now longer than the length of the half wave on the record, cannot follow the groove and consequently it rides up and down and its lateral motion, not being sinusoidal, introduces harmonics. The pressure per square inch which forces the needle closely to follow the groove is decreased as already pointed out and this aids eccentricity of movement. The phenomena which have just been discussed lead to attenuation, especially of high notes, as the amplitude of the moving needle is less than the amplitude of the recorded wave. In a measured case this attenuation amounted to 4db. for a frequency of 5000 cycles. Some of the Dominion records were very bad in this respect. It was necessary to use two and sometimes three new needles for each of the first six or seven playings of a given record. As the Dominion Company changed the formula of their record many times, this trouble only occurred in certain cases. The difficulty may obviously be considerably decreased (but not cured) by recording from the inside outwards as is done with talking picture records and as Berliner mentioned in his original patent specification of 1888.

13. *Occlusions* in the plastic moulding stock vary in nature and degree. It is more appropriate to comment upon the freedom of commercial records from this defect than upon the rare occasions when they are found. In most cases they have no effect whatever upon the correct functioning of the record, but there is always the possibility that they may be picked out by the reproducing point, causing a cavity that completely ruins the record. Figure 38 shows a typical case and, although thousands of records may be scrutinised without finding a speck, it may so happen that a whole batch is affected.

14. *Blisters* are due to the liberation of gas, usually water-vapour, during manufacture. The generation of vapour is a normal consequence of the heat treatment of many thermoplastic compositions, and care has to be taken to prevent it from affecting the product in any way. Occasionally the gas pressure may rise, by chance at a point where the moulding stock is not well mixed. One record of a popular cheap make offered over the counter in Bloomsbury a few weeks ago had an eruption as large as a threepenny piece on its playing surface. Unfortunately it could not be secured for this review, but the one illustrated in Figures 39 and 40 is now in the Editor's hands. The comparison made in Figures 40 (*a*) and (*b*) is singularly fortunate since it shows what happens when the needle passes over such a blister for the first time.

15. *Pull-outs.*—Of all the evils to which records are heir, those known as "pull-outs" probably surpass any other two put together for malignancy. A pull-out signifies that the disc is not quite complete, a portion of the stock having adhered to the stamper—usually a tiny fragment at the bottom of a groove. Pull-outs can occur for a variety of reasons or for no apparent reason whatsoever. A large factory in England at one

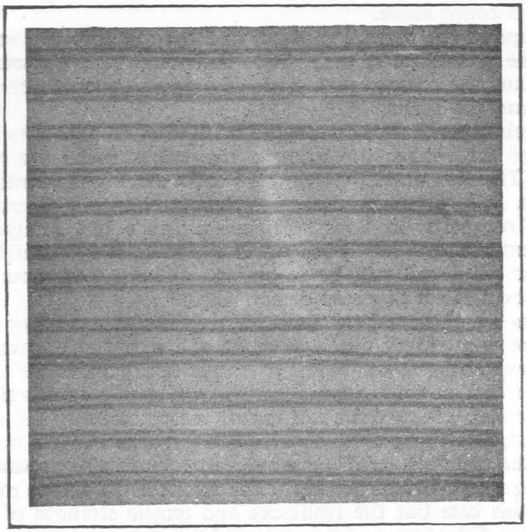

FIG. 38.—See *Occlusions*.

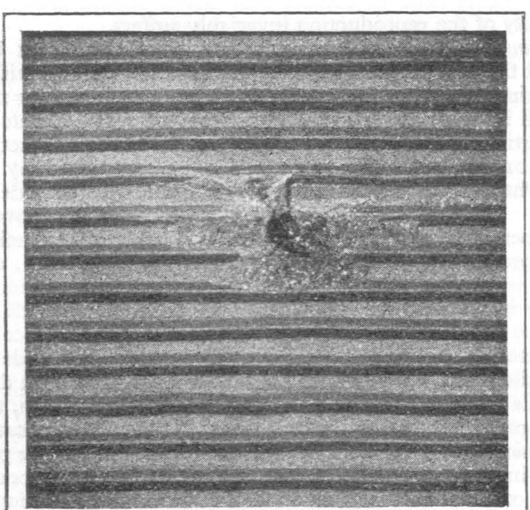

FIG. 39.—See *Blisters*.

time in its history was turning out three bad records for every two good ones, on this count alone.

The shape of the recording stylus and the methods of recording both influence the prevalence of pull-outs. As would be expected, the deeper the groove and the narrower the angle of the cutting stylus, the more liable to trouble are the records.

Very high notes also heighten the likelihood of pull-outs, the sudden curvature of the groove providing a convenient niche for the stock to lodge in. The low tensile strength of solid stock considerably aids any tendency in this direction, though materials with ten times the tensile strength of normal solid stock will pull-out on a bad stamper. Once a tiny fragment becomes firmly lodged in a groove, it will remain there and every record produced will be imperfect. These fragments may be so small as to be difficult of visual detection.

Stampers which have been used on very hard material or on material which is not very plastic (such as some of the newer unbreakable compositions), especially where higher pressures than normal are used, show a tendency for the grooves to bend outwards after the production of a few hundred records. If the composition or temperature of the plating bath is not correct, microscopic bubbles may be produced in the bottom of the grooves of the matrices. Adhesive solid impurities also produce the same effect, giving a cave-like structure. The matrices are a little more difficult to strip in this case but the resilience and tensile strength of the copper prevent undue distortion, and it is not until the stamper gets into production that the trouble appears. When a pull-out occurs, the adhering fragment may sometimes be removed, by the exercise of care, with a fragment of bone or wood. Nothing harder may be employed. Obstinate cases have to be treated with methylated spirit and persistent cases sometimes yield to delicate treatment with special tools. This latter procedure, which is also sometimes used to correct false notes, should always be avoided as the quality of the reproduction invariably suffers.

16. *Swingers.*—In record manufacture great care must be taken to ensure that the hole in the middle of the record coincides with the centre of the Archimedian spiral formed by the recording grooves, or the produced records will be what are known as swingers and will fluctuate in pitch on each revolution of the turntable. The human ear can detect a centering error of 0·01 in. A swinger can readily be recognised by the eye by noticing whether the sound box sways from side to side with each revolution. The most harmful swingers are those which move in jerks.

A stamper, itself perfectly concentric, is capable of producing swingers if, during production, it slips slightly under the centre pin, due to wear or some other cause. The smaller the diameter of the sound circle, the more acute is the trouble. Consider a six-inch sound-circle, containing a note of 500 p.p.s., on a record which is one-eighth inch off-centre. With correct centering 500 sinousities per second would pass under the reproducing needle point, but owing to the fact that the maximum displacement of the needle during a rotation of 180 degrees is quarter inch, the speed at which one part of the record passes under the needle is greater than the speed at which the corresponding part diametrically opposite passes under the needle in the ratio of $6\frac{1}{8}$, $5\frac{7}{8}$, or 49, 47, *i.e.*, about 4 per cent. So, instead of a constant note with a period of 1/500, there is a rising and falling note with a period varying between 1/490 and 1/510. Now, consider a smaller, say three-inch, sound-circle on the same record. The effect is greater because the ratio of the linear velocities is greater. The swing is now between $3\frac{1}{8}$ and $2\frac{7}{8}$, *i.e.*, 25, 23, or about 8 per cent., so that

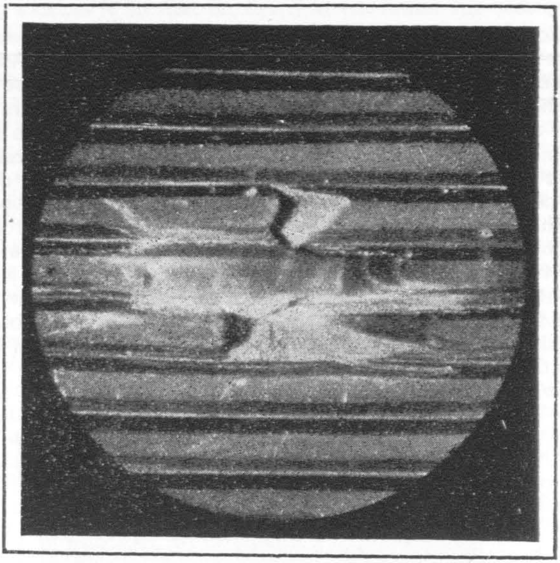

FIG. 40 (*a*).—See *Blisters*.

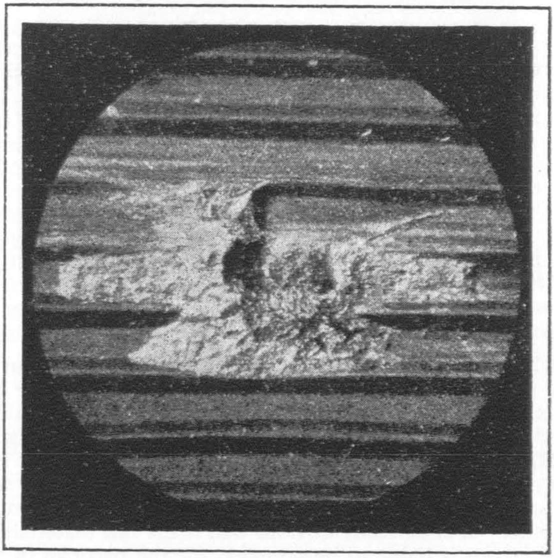

FIG. 40 (*b*).—See *Blisters*.

the frequency fluctuates between 480 and 520 for each half-revolution of the record.

A musical ear can detect variations of pitch of 1 per cent. over a fairly wide range—2 per cent. begins to mar the reproduction. Assume that at the end of a record the distance of the needle from the centre is $1\frac{1}{2}$ inch and that the record is ·01 inch off-centre; then the velocity ratio is 1·51 to 1·49, or about $2\frac{1}{2}$ per cent. In other words, the maximum amount of swing permissible on a record is ·01 in. as already stated, especially if fibre needles are employed, which seem to accentuate this form of defect.

Some people hold the extraordinary view that solid stock records are better with an oversized central hole because centering errors can be corrected by watching the sound-box while the needle traverses the first groove or two and then, if swaying occurs, giving the record a gentle tap inwards with the finger-nail just as the sound-box reaches the outermost point in its swing. However effective this may be with a really bad swinger, the possibility of correcting a centering error of one-hundredth of an inch by this method is so remote as to be an impossibility.

17. *Surface Noise* is due in some measure to the finite size of the

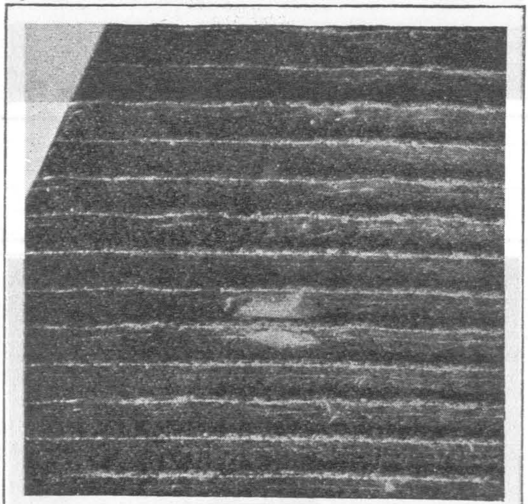

FIG. 41.—Photo-micrograph showing Pull-out.

particles which constitute the record. Other causes of surface noise have been discussed above. The plastic material is made by mixing shellac plus other natural or synthetic gums with a filler such as slate powder and a colouring agent, *e.g.*, carbon black, and a toughener like cotton flock, on horizontal steam heated mixing mills. After rolling, the material is ground to 200 mesh and then either remixed and sheeted out or spread on paper discs to make laminated records on a centre core of cheaper plastic. It is perfectly obvious that if the raw materials are coarse the finished record is liable to be scratchy, for the particles of filler when the pressure is released are likely to spring out slightly from their resinous matrix and form a slight obstruction to the needle as it traverses the track.

The knock which the particle gives the needle, and which is reproduced as scratch, loosens it so that on the next encounter the scratch is worse till finally the particle is knocked into the bottom of the groove, there to cause more annoyance. Experience has shown that particles smaller in diameter than 0·007 in. do not give much trouble in this respect. The cotton flock employed gives rise to a similar series of troubles, and at least one of the largest companies now uses none at all. Shellac on exposure to air increases in weight by oxidation. When records are not carefully made—for example for the sake of economy the temperature range may be cut down during pressing—alteration can occur on the surface due to two causes. Firstly, the shellac in oxidising increases slightly in volume and has a tendency to push up the cotton flock into minute ridges all over the face of the record, and secondly, if the cooling under pressure (which permits only two dimensional contraction) is insufficient, on removal the record will suffer three-dimensional shrinkage, thus diminishing its lustre, the dullness being due to irregular movements of the surface in the vertical plane causing roughness and needle scratch. Examination of very cheap records sold in multiple shops and comparison with expensive ones will quickly demonstrate these points. In passing it should be noted that this is a fault quite distinct from record wear (which is usually selective for certain notes) though a rough surface will obviously accentuate this trouble.

18. *Uneven thickness.*—With certain types of record press, the back or neck of the press is apt to become stretched in the course of time, and the upper and lower platens cease to be parallel. This is especially true of certain types of American press. Apart from the strain on the stampers, which are then more easily stretched, the produced record is seldom of uniform thickness. Now the ordinary gramophone needle is seldom as sharp as the recording stylus, and therefore rarely reaches to the bottom of the groove. Consequently two chisel faces are worn on the needle, which owing to its slope and the sinuosities of the groove, presents first one cutting edge then the other to alternate sides of the track. The needle then rides up and down on the grooves, and this movement may be accentuated by variation in thickness of the record. Incidentally, this is the reason that a new needle should be used for every record, as the chisel edge worn by the final grooves would not fit the initial ones of another, or even the same, record.

19. *Label Errors.*—Strange though it may seem, the labelling of a record presents a number of problems for the manufacturer, but, with one exception, these are of little consequence to the ordinary gramophile. The exception is incorrect titling, which, in most cases, is due to confusing the two sides of one record. The trouble is too obvious to need stressing.

20. *Cracks and Crevices.*—Records sometimes develop cracks without apparent reason. Broadly speaking, these are of two types, the commoner being radial cracks starting as a hair line at the edge of one face and gradually extending towards the centre and sometimes to the other face. Less frequently the crack appears as a crescent shaped flaw on the playing surface. Both types give rise to the familiar click as the flaw passes under the needle. These cracks are due to static stresses set up in the material during manufacture. The actual cause is most likely to be faulty temperature control. As they develop some time after manufacture the loss generally has to be sustained by the purchaser, which is not as it should be. It would be interesting to hear what the leading manufacturers have to say about it.

21. *Buckling.*—This defect is included for the sake of completeness. Fortunately it can be remedied by gentle pressure, aided by heat. The cause may be the same as in 20 above, but is far more likely to be careless storage.

Defects in Gramophone Records.

(1) (*a*) MAXFIELD & HARRISON.

High Quality Recording and Reproducing of Music and Speech. Jnl.Am.I.E.E. Feb. 1926.

(*b*) WHITAKER.

Progress in Recording and Reproduction of Sound. Jnl.Sci.Insts. Feb. 1928, p. 37.

(2) H. A. FREDERICK.

Recent Advances in Wax Recording. Bell Lab. Record. Nov. 1928.

(3) H. C. BRYSON.

The Manufacture of Gramophone Records. British Plastics. Vol. I, pp. 187, 326, 442, 484, 539, also Vol. III.

(4) Dr. W. McLACHLAN.

Improvements in or Relating to Thermionic Amplifiers for use with Electric Gramophones and the like. British Patent No. 328,331 of 1929.

(5) P. WILSON.

THE GRAMOPHONE. Feb. and March 1930, pp. 424, 471 ; Sept. 1931, p. 165.

(6) SERGE RACHMANINOFF.

THE GRAMOPHONE. April 1931, pp. 525-6.

(7) MUSIC CRITIC " C.J."

Review of Piano Records. THE GRAMOPHONE. May 1928, p. 500.

APPENDIX II.

OHM'S LAW SIMPLY EXPLAINED.

Many readers, although they are capable of constructing a wireless receiver, or an electric amplifier, or a complete radio-gramophone from published diagrams and details, may be utterly at a loss to grasp the meaning of what is known as Ohm's Law. They know that *Current* is the amount of electricity flowing in a conductor, and is measured in *Amperes.* They know that the Electromotive Force is the pressure required to make the current flow and that the Electromotive Force (usually written E.M.F.) is measured in *Volts.* They know that the *Resistance* in a conductor is that force which opposes the flow of current, and that the unit of measurement of resistance is the *Ohm.* They know that the unit of *Power* is the *Watt* and that 1 watt is the product of 1 ampere and 1 volt.

They probably know the difference between *Direct Current* and *Alternating Current.* But what they do not know, and this is a common stumbling block, is how to put all these facts into practical use. Ohm's Law enables us to do this. When we are dealing with *Direct Current* the basic quantities with which we are concerned are the Electromotive Force, measured in volts, the Resistance measured in ohms, and the Current measured in amperes. All are related by Ohm's Law. Instead of writing down Electromotive Force, Resistance and Current, each of these quantities are given designating letters. Thus we substitute

E for Electromotive Force.
R for Resistance.
I for Current.

(Incidentally, the symbol I is used to indicate current because the letter C is wanted to represent Capacity.)

Ohm's Law can then be written in any of the following ways :—

$$I = \frac{E}{R}; \ R = \frac{E}{I}; \ E = I \times R.$$

There are some people who, when they see a formula in terms such as this, immediately shake their heads and say: "Oh! Algebra. That stuff is beyond me." But really if they can be persuaded to look at it sensibly they seen find out how easy it all is. Formulae are only ways of writing down complicated ideas in a sort of shorthand and when once that has been done the ideas even cease to be complicated. One uses them just as instinctively as one walks : and walking is a very complicated process to an infant. Just look at Ohm's Law from this point of view and you will find that the difficulties begin to disappear.

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

This short expression summarises quite a number of common sense ideas. Assume, first of all, that we have a battery which gives a steady pressure E volts. This might be 2, or 6, or 10 or 1,000 volts ; it doesn't matter to the argument, so long as the pressure is fixed to start with and through the experiment. Suppose, then, we were to connect up to this battery a piece of wire which has an electrical resistance R ohms, one end of the wire going to one "terminal" of the battery and the other end to the other terminal. Then Ohm's Law tells us that the current that will flow in the wire will have a value in amperes which will be obtained by dividing the pressure in volts by the resistance R in ohms ; in other words, the greater the resistance of the wire the smaller the current that will flow. Surely that is obvious common sense? If we double the resistance of the wire we shall halve the current; and if we halve the resistance we shall double the current. Or again, if we increase the resistance to 3, 4, 5, or any number (n) times the original value we shall get a current of $\frac{1}{3}$, $\frac{1}{4}$, $\frac{1}{5}$, or in the general case $\frac{1}{n}$ times the original value. All these statements are summed up in the expression $I = \frac{E}{R}$. But that does not by any means exhaust the meaning. Instead of changing the piece of wire we might have continued with the same piece and used a battery of smaller or larger voltage. In that case Ohm's Law tells us that if we multiply the pressure by a certain amount, the current flowing will be multiplied by the same amount; twice the pressure will yield twice the current; three times the pressure, three times the current, and so on. Or again, we might have used two distinct pieces of apparatus with different pressures and different voltages. Ohm's Law summarises for us what will happen in these cases also. Thus, if we double both pressure and resistance we shall get the same current; if we double the pressure and use three times the resistance we shall only get $\frac{2}{3}$ as much current, and so on.

Series Connections.

Look at the formula in the form $E = I \times R$. Suppose we have a number of pieces of wire all connected together end to end and then connect the two extreme ends, one to each terminal of a battery. One terminal of the battery (the "positive" terminal, which is usually painted red) is at an electrical pressure of E volts above the other ("negative" or black) terminal. As the current flows through the pieces of wire, therefore, from one end to the other the pressure must decrease from point to point: in other words, the resistances are said to "drop volts." Ohm's Law tells us how many volts will be dropped in each or any of the resistances: in any resistance R the voltage dropped will have a value equal to the current passing, measured in amperes, multiplied by the resistance, measured in ohms. In the whole chain, if we denote the separate resistances by R_1, R_2, R_3 etc., the total voltage dropped will be:

$$I \times R_1 + I \times R_2 + I \times R_3 + \text{etc.},$$

the current being the same through all the resistances. The sum of these terms must therefore be equal to the total voltage E. So

$$E = I \times R_1 + I \times R_2 + I \times R_3 + \text{etc.}$$

Dividing each side of this expression by I, we see that

$$\frac{E}{I} = R_1 + R_2 + R_3 + \text{etc.},$$

so that resistances connected "end on" like this act just like a single resistance equal to the sum of the individual resistances: a thing which should be tolerably obvious from common sense principles since when we speak of the resistance of a piece of wire we can only mean the sum of the separate resistances of each little length of which the wire is composed.

In a case such as this where the pieces of wire are joined together "end on" the connections are said to be in *series*. The formula for the total resistance R of a number of resistances R_1, R_2, R_3, etc., connected in series is thus seen to be:

$$R = R_1 + R_2 + R_3 + \text{etc.},$$

and Ohm's Law has also shown us two additional things: first, that the current I flowing through each resistance will have a value $\frac{E}{R}$ and second, that between the two ends of any particular resistance R_1 there will be a difference of electrical pressure (or in other words a "drop of voltage") of $I \times R_1$. So, to find the drop of voltage in any resistance in this case all we need do is first of all to calculate the current flowing and then to multiply that by the value of the particular resistance.

Parallel (or Shunt) Connections.

But what would have happened if, instead of joining the pieces of wire to each other "end on" and the extreme ends to the battery, we had joined the ends of each piece of wire to the battery? Obviously, there will be a greater current drain from the battery, but how much? Assuming that the difference of pressure (which is sometimes called the "potential difference") between the two terminals of the battery remains the same whatever circuit is connected between them, it seems reasonable to conclude that the same current will flow through each resistance as though the other resistances were not joined up. Ohm's Law tells us that this is the case. Thus, the pressure E being the same for all the resistances, the current flowing through any resistance R, will be given by $I_1 = \frac{E}{R_1}$

The total current flowing from the battery will thus be:

$$I = I_1 + I_2 + I_3 + \text{etc.}$$
$$= \frac{E}{R_1} + \frac{E}{R_2} + \frac{E}{R_3} + \text{etc.,}$$

and therefore

$$\frac{I}{E} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \text{etc.}$$

If, therefore, we denote by R the equivalent resistance of all these resistances connected in parallel we must have

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

and therefore

$$\frac{1}{R} = \frac{I}{E} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \text{etc.}$$

This, then, is the rule for finding the equivalent resistance of a number of resistances connected in parallel: the reciprocal of the total resistance is the sum of the reciprocals of the individual resistances. The reciprocal of R is $\frac{1}{R}$, the reciprocal of 1 is $\frac{1}{1}$, the reciprocal of 8 is $\frac{1}{8}$, and so on.

Example.

Suppose we have four resistances of various values, say 2, 5, 8 and 12 ohms. If they are connected in series the total resistance will be

$$2 + 5 + 8 + 12 = 27 \text{ ohms.}$$

If these same resistances are connected in parallel we get, taking the reciprocals

$$\frac{1}{R} = \frac{1}{2} + \frac{1}{5} + \frac{1}{8} + \frac{1}{12} \text{ ohms.}$$

Since it is impossible to add up these fractions as written, it is necessary to either convert them into decimals or to find the least common denominator. In most cases it is easier to express the fractions in decimals, thus

$$\frac{1}{R} = 0{\cdot}5 + 0{\cdot}2 + 0{\cdot}125 + 0{\cdot}083$$

$$\frac{1}{R} = \frac{{\cdot}908}{1}$$

reversing the numerators and denominators

$$\frac{R}{1} = \frac{1}{{\cdot}908}$$

R divided by 1 is simply R, so

$$R = \frac{1}{{\cdot}908} = 1{\cdot}1 \text{ ohms.}$$

Notice there is no abracadabra about it. The whole thing is logical and straightforward. In the case of series connections we have the same current going successively through a number of resistances and obviously the total resistance or opposition to the flow of current is equal to the sum of the individual resistances. In the case of parallel connections we have the same pressure between the ends of each resistance, so the current flowing in each resistance will vary according to the values of the individual resistances; the net result is not obvious but is easily found by a simple calculation.

Cautions.

Before we pass on to practical examples, a few words of caution are necessary. In the first place, Ohm's Law in the form already given only applies to *Direct Currents,* that is where the flow is steadily in one direction, as it is when the source of electrical pressure is a battery. In the case of *Alternating Currents,* we use electrical pressures which are continuously varying, and the current surges backwards and forwards, first in one direction and then the other. In this case other factors such as *inductance* and *capacity* have to be taken into account as well as resistance, just as mass and spring as well as friction are involved in the analogous case of mechanical vibrations. In the second place, the assumption made above that the source of pressure is unaffected by the circuits connected to it must not be lost sight of. Some sources of pressure alter their voltage according to the amount of current that is being taken out through the resistances in the external circuit and then care has to be taken in finding the current that will actually flow. Ohm's Law still applies provided that at each stage the actual pressure appropriate to the circumstances of the resistance load is used for the purpose of calculation. The point is of great importance and is responsible for many misconceptions about the use of Ohm's Law. A fully charged battery does give a constant pressure provided too much current is not taken from it. On the other hand, the pressure of a battery which is run down or of an H.T. or L.T. eliminator may vary considerably with the current taken.

Condensers and Batteries.

Whilst we are on the subject of series and parallel connections it would be well to clear the air regarding the series-parallel connections of condensers and batteries.

The value or *Capacity* of condensers used in wireless sets and electric amplifiers is always stated in *Microfarads,* usually abbreviated (mfd.).

One mfd. is the millionth part of a farad, which is the standard unit. Thus we say a condenser, whether it is of the fixed or variable type, has a Capacity of so many Microfarads. When condensers are connected in *series* the same rule applies as for resistances in *parallel*. When condensers are connected in *parallel* the rule applicable is as for resistances in *series*. Example: If two 2-mfd. condensers are connected in series the total capacity is 1 mfd.; if they are connected in parallel the total capacity is 4 mfd.

When a number of accumulator or battery cells are connected in *series* the total E.M.F. (voltage) is the sum of the E.M.F's of each cell. Example: If we have two 2-volt cells and we connect the positive terminal of one to the negative terminal of the next cell they are connected in series and the total E.M.F. will be 4 volts.

But when the cells are connected in *parallel* the total E.M.F. is that of a single cell.

Example: If the positive terminals of two 2-volt cells are connected together and the two negative terminals are connected together the total E.M.F. will be 2 volts.

Coming back to Ohm's Law, we know that $I = \frac{E}{R}$; so if, for example in an electrical circuit there is an E.M.F. or pressure of 100 volts and a resistance of 25 ohms, and we wish to find the amount of current flowing, we get, substituting 100 for E and 25 for R:

$$I = \frac{100}{25} = 4 \text{ amperes.}$$

If we wish to express the current in Milliamperes (ma.) the answer must be multiplied by 1,000 as there are 1,000 ma. in 1 ampere.

Alternatively the above expression can be written:

$$I = \frac{100}{25} \times 1{,}000 = 4{,}000 \text{ ma.}$$

With the aid of the second formula $R = \frac{E}{I}$ we prove that the resistance in the circuit is 25 ohms:

$$R = \frac{100}{4} = 25 \text{ ohms.}$$

The third formula, $E = I \times R$, proves that the value of E is 100 volts:

$$E = 4 \times 25 = 100 \text{ volts.}$$

Practical Examples.

Now we will start all over again with the first formula $I = \frac{E}{R}$ giving more practical examples.

(1) Suppose we have a resistance of 30,000 ohms rated to carry a current of 10 ma. and we wish to place this across the H.T. line of a set. Before doing this we have to satisfy ourselves that the current flowing does not exceed 10 ma. otherwise the resistance will break down. Assuming the voltage to be 240, then the current

$$I = \frac{240}{30{,}000} \times 1{,}000 = 8 \text{ ma.}$$

Thus the resistance will be quite all right.

(2) In most of the valve manufacturers' catalogues the anode volts, grid bias values and anode current consumed are given in actual figures.

For instance, look on page 34 of the Marconi catalogue. There you will see the operating data for various A.C. valves. For this example we will take the figures for the M.L.4 valve. Here the anode current consumed is 18 ma., with an E.M.F. of 150 volts applied to the anode and a grid bias value of 6 volts.

Suppose we wish to find the value of resistance required to drop 80 volts with an initial E.M.F. of 230 volts. We know that 18 ma. expressed in amperes is ·018 (18 divided by 1,000) and that the formula to use is $R = \frac{E.}{I}$ Take notice that since we wish to drop 80 volts, this is the value of E.

$$R = \frac{80}{\cdot 018} = 4444{\cdot}44 \text{ ohms}$$

The nearest commercial resistance is 4,500 ohms.

(3) Now we will prove that approximately 80 volts will be dropped by using this commercial value of resistance.

$$E = I \times R = \cdot 018 \times 4{,}500$$
$$E = 81 \text{ volts.}$$

Note also that since the volts dropped is 81 and the current passed is 0·018 amps. the wattage rating of the resistance must be not less than $81 \times \cdot 018 = 1{\cdot}45$. So one would use a 2 watt resistance.

(4) Consider the filament circuit of a valve with a series resistance to

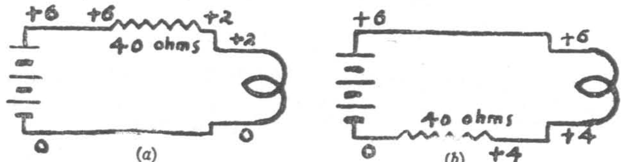

FIG. 42.—Diagrams showing stages of pressure with resistances in (*a*) positive and (*b*) negative filament leads of an S.G. 210 valve to control current.

control the current. Thus suppose we have a 2 volt valve whose filament takes 0·1 amps., say an S.G. 210. The resistance of this filament is 20 ohms since $\frac{2}{0{\cdot}1} = 20$. Now the valve must not be used in such a way that more than 0·1 amp. passes through the filament. To save complications in connection with the other valves in the set, we want to use a 6 volt battery, so we insert a series resistance in the filament circuit sufficient to drop 4 volts. The resistance required is clearly $\frac{4}{0{\cdot}1} = 40$ ohms. Counting the filament resistance of 20 ohms we now have $20 + 40 = 60$ ohms across the 6 volt battery. The current flowing will thus be $\frac{6}{60}$ or 0·1 amp., as it should be. Now notice that it does not matter for this purpose whether we put the series resistance in the positive or negative lead to the filament. If we put it in the positive lead (*i.e.*, on the side nearer to the positive terminal of the battery) the series resistance will be at a pressure above that of the filament. But if we put the series resistance in the negative lead it will be at a negative pressure with respect to the filament. Thus in diagrammatic form we have the following stages of pressure: *see* Fig. 42.

There are 2 volts difference across the filament in each case, but in the first case one end of the filament is at the same pressure as the negative terminal of the battery, whereas in the other case it is 4 volts above. In the latter case, then, if we were to connect the grid return lead to the negative terminal of the battery it would be at a potential of 4 volts below the negative end of the filament. In other words, the valve would have an "automatic" or "free" negative grid bias of −4 volts.

But this is usually too large for our purpose, so we adopt the expedient of connecting part of the 40 ohms resistance in the negative lead and part in the positive lead. How much of it should be connected in the negative lead to give a bias of $1\frac{1}{2}$ volts? Since the current passing is 0·1 amp. the value required is clearly $\frac{1\frac{1}{2}}{0 \cdot 1}$ or 15 ohms. So we should use 15 ohms in the negative lead and the remaining 25 ohms in the positive lead. In this case we have the following succession of voltages along the circuit (Fig. 43).

Here are two problems for you to work out yourself. Try them before reading the answers at the end.

Problem 1.—Work out the value of resistance required in the positive and negative leads of an S.G.215 valve to give a bias of 0·9 volts, using a 4 volt battery.

Problem 2.—Find the value of resistance required under the following circumstances. The initial E.M.F. is 200 volts. The valve passes a current of 6 m.a. with 150 volts H.T. The E.M.F. desired on the plate of the valve is 150 volts. From your answer find out the actual voltage dropped when using the nearest commercial value of resistance.

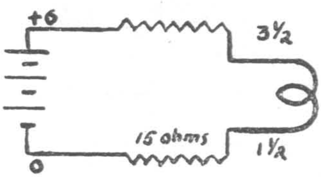

FIG. 43.—Diagram showing succession of voltages, with resistances in both positive and negative filament leads of an S.G. 210 valve.

(5) Suppose we wish to provide automatic grid bias for the output stage of a receiver or amplifier in which the power valve is of the indirectly heated type, say a Mazda AC/P1. :

There are alternative ways of doing this, but for this example we will insert the resistance in the cathode lead, with, of course, a condenser in shunt. The operation of this is quite simple. Negative electrons are passing from the cathode of the valve to the plate. So there is a positive current from the H.T. battery passing from the positive terminal to the plate, through the valve to the cathode and thence through the resistance to H.T. −. This current is the anode current of the valve and it causes a drop of voltage in the resistance in the cathode lead. The actual cathode is thus at a positive potential relative to H.T. − and if the mean potential of the grid of the valve is the same as H.T. − it follows that the grid is negative relative to the cathode. The resistance in the cathode lead thus gives the valve a negative grid bias. Notice, however, that the H.T. voltage actually applied between plate and cathode is not the full voltage between H.T. + and H.T. − : it is that voltage less the voltage used as grid bias. So the bias is not really "free" as is sometimes supposed. Very few things are in this world. The condenser (usually of the order of 2 mfds.) is shunted across the resistance because in practice the anode current varies about its mean value according to the signal applied to the grid. The condenser will by-pass a large proportion of the variation of the current and thus stabilise the current passing through the kathode resistance and therefore keep the grid bias more or less constant.

This method of automatic biasing is popular in American receivers, but although it usually functions satisfactorily, it is not above reproach as the filament may be at a different potential from the cathode if several valve filaments are fed from one transformer winding. We will assume that the E.M.F. available after rectifying and smoothing is 230 volts. With a grid bias of 32·5 volts and 200 volts on the plate, the AC/PI consumes approximately 15 ma. H.T. or in other words ·015 amps. To find the value of resistance required to drop 32·5 volts, we obviously use the formula

$$R = \frac{E}{I} = \frac{32 \cdot 5}{\cdot 015} = 2{,}166 \text{ ohms.}$$

The nearest commercial value is 2,000 ohms. Now we must ascertain how many volts are actually dropped with this value of resistance in circuit,

$$E = I \times R = 2{,}000 \times \cdot 015 = 30 \text{ volts.}$$

This value of bias is quite all right. But do not forget that the resistance

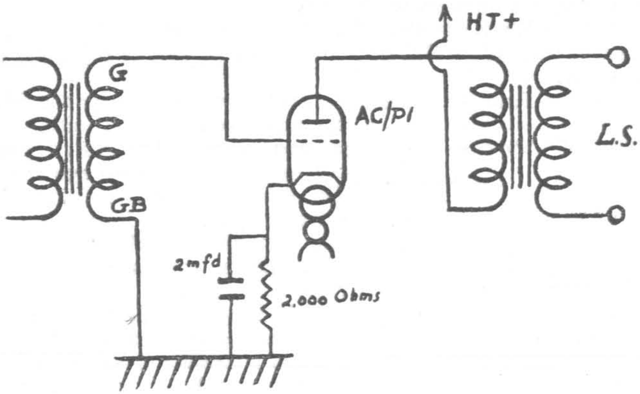

FIG. 44.—Method of obtaining automatic grid bias with resistance in Cathode lead.

must be capable of passing 15 ma. without overheating. The condenser can be of the 200 volt test type as it only has to stand 30 volts, the bias value.

Here is the arrangement in diagrammatic form : *see* Fig. 44.

(6) Now consider two AC/PI valves used in push-pull. We can, of course, provide automatic bias by putting a 2,000 ohm resistance in each kathode lead as in the previous example. But we can in practice make one resistance and one condenser bias both valves. Since one AC/PI consumes a current of 15 ma. two will consume 30 ma. It is clear, then, that the value of resistance required to drop 30 volts will be halved.

$$R = \frac{30}{\cdot 030} = 1{,}000 \text{ ohms.}$$

In this case also the grid bias terminal of the push-pull transformer is connected to earth, the cathodes of the two valves are connected together and the resistance and condenser inserted in the lead from the cathode to H.T.— or to earth. The resistance must pass 30 ma. without overheating.

(7) Here is another example. A man while living in France bought an Era electric gramophone motor. This is a 26 volt model which consumes 0·4 amperes. The mains supply in his particular locality was 100 volts,

and to drop the necessary volts he used a special lamp supplied by the makers. But after taking up residence in England, he was at a loss to know what lamp or lamps to use. The calculation is as follows. We want to reduce the voltage from 240 to 26, *i.e.*, by 214 volts. So 210 volt lamps (the nearest commercial lamp) are suggested. To find the wattage required, we note that we wish to pass 0·4 amperes.

$$\text{Volts} \times \text{Amps.} = \text{Watts}$$

$$\therefore 210 \times 0{\cdot}4 = 84 \text{ watts.}$$

Since no manufacturer makes 84 watt lamps the best we can do is to use two 40 watt lamps in parallel.

(8) As an example of a more exact method of calculation let us see the effect of two such lamps in parallel used with 230 volt mains. When a 40 watt lamp is connected direct to 210 volt mains, it will pass $\frac{40}{210} = {\cdot}19$ amps. (amps. $= \frac{\text{watts}}{\text{volts}}$). So its resistance is $\frac{210}{{\cdot}19} = 1{,}100$ ohms approximately, (ohms $= \frac{\text{volts}}{\text{amps.}}$). Two such lamps in parallel will therefore have a resistance of half this, that is, 550 ohms.

Now consider the motor which is in series with these parallel lamps.

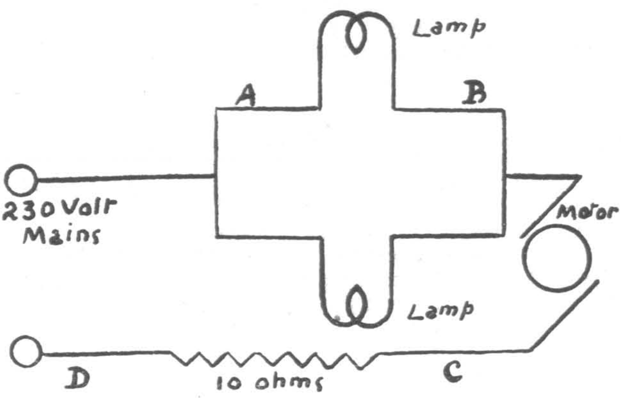

FIG. 45.—Diagram showing two lamps in parallel to reduce mains voltage to suit voltage of gramophone motor.

At 26 volts it passes 0·4 amps., so its equivalent resistance in these conditions is $\frac{26}{0{\cdot}4} = 65$ ohms. The total resistance in circuit is therefore $550 + 65 = 615$ ohms. But the total resistance we want must be such that when connected in a 230 volt circuit 0·4 amps. is passed. This resistance is therefore $\frac{230}{0{\cdot}4} = 575$ ohms. Our resistance is thus too big, and in consequence the motor will not get its full 26 volts. We must therefore reduce the lamp resistance; that is to say, the lamps must pass more current. We may either increase the wattage (remember, we got 84 watts) or we may decrease the voltage rating. Let us try 200 volt, 40 watt lamps. The current passed by one of these is $\frac{40}{200} = 0{\cdot}2$ amps and its resistance is therefore $\frac{200}{0{\cdot}2} = 1{,}000$ ohms.

The resistance of two lamps in parallel is thus 500 ohms and the current passed will be 0·4 amps., which is what we want. The total resistance with the motor will be 565 ohms. This is 10 ohms too little, so we insert a 10 ohm resistance in series. Here, then, is the circuit: *see* Fig. 45.

It doesn't matter which of the two leads to the motor contains the 10 ohm resistance, but for convenience in the diagram it is shown in the lead which does not include the lamps. The voltage drop along the circuit is easily calculated as follows:

(Current flowing is 0·4 amps.)

Resistance AB = 500 ohms.	Voltage drop	= 0·4 × 500 =	200
„ BC = 65 ohms.	„ „	= 0·4 × 65 =	26
„ CD = 10 ohms.	„ „	= 0·4 × 10 =	4
Total	„ „	=	230

and all is right as right can be.

Solutions to Problems on Page 94.

(1) The total resistance required to drop 2 volts is:

$$R = \frac{2}{0{\cdot}15} = \frac{40}{3} = 13\tfrac{1}{3} \text{ ohms.}$$

Resistance in the negative lead is:

$$R = \frac{0{\cdot}9}{0{\cdot}15} = 6 \text{ ohms.}$$

∴ Resistance in positive lead = $7\frac{1}{3}$ ohms.

(2) $$R = \frac{E}{I} = \frac{200-150}{{\cdot}006} = \frac{50}{{\cdot}006} = 8{,}333 \text{ ohms.}$$

The nearest commercial resistance is 8,000 ohms.

$$E = I \times R = {\cdot}006 \times 8{,}000 = 48 \text{ volts,}$$

so that the E.M.F. applied to the plate of the valve would be 152 volts, which is quite near enough to 150 for our purpose.

APPENDIX III.

PICK-UP CONNECTIONS.

Suppose you wish to connect a pick-up to a wireless receiver which has no special terminals provided for the purpose. How would you proceed? Two points must be decided for a start. The first is whether the receiver has sufficient low frequency amplification on the radio side that it will not be necessary to use the detector valve as a low-frequency amplifier when the pick-up is being used. This will only be the case if there is at least one L.F. stage apart from the output stage. If modern valves are used two stages of amplification are usually sufficient unless an output valve requiring a very big input voltage (of the order of 100) is used. It is to be noted, however, that a 3 stage L.F. amplifier with a low gain per stage usually gives a distinctly better quality of reproduction than one of 2 stages. Converting a detector valve into an amplifier when switched over to a pick-up complicates the switching, but often proves to be worth while. Another consideration should be noted at this point. If the detector is of the grid-leak variety it has no negative bias and the anode current is consequently high; when bias is switched in so that the valve may be used as an amplifier the anode current falls and if decoupling resistances are used in the anode circuit the voltage drop in them will be

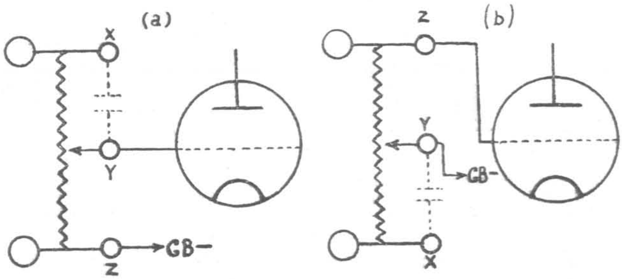

FIG. 46.—Potentiometer volume control for pick-up.

reduced with the result that the actual H.T. voltage at the anode of the valve should go up. This is an advantage. On the other hand, if an anode bend detector is used, the voltage at the anode of the valve will be reduced when switched over to pick-up and this can be a distinct nuisance since the valve will then be more easily overloaded.

This leads to the second preliminary point: the necessity, or otherwise, for a volume control between the pick-up and the amplifier. If there is no L.F. volume control incorporated in the amplifier itself a control immediately after the pick-up is of course always required. The usual method, shown in Fig. 46 (*a*) is to connect a potentiometer across the pick-up with its slider going to the grid of the valve. The connection of a load resistance across the pick-up in this way reduces the response to high notes; in fact reducing the total ohmic value of such a resistance is probably the best way of cutting down an excessive high note response. The unfortunate thing is that the setting of the slider of the potentiometer also affects quality: when the volume is reduced high notes begin to disappear first, which is precisely what they should *not* do. An alternative form of connection is shown in Fig. 46 (*b*), but this is open to the same objection. It is often better than the arrangement in Fig. 46 (*a*) however, in that it may reduce or avoid a certain spurious hum that sometimes arises.

When a relative increase of high notes is required, a condenser may be connected between the points X and Y as shown. The value of the condenser required varies with the pick-up and according to the amount of lift that is wanted. One of the semi-variable type of maximum value 0·002 mfd. will usually be suitable. If this is made accessible one has a sort of high tone control, the relative high note minimum, of course, being achieved at full volume. Incidentally the same sort of device may be used in the amplifier itself when there is a resistance-capacity stage, the potentiometer then being the grid leak. Sometimes it is an advantage to connect a second condenser (either fixed or semi-variable) in parallel with the first in order to obtain a different range of control. Another trick that can be tried is to connect a fixed resistance of the order of 100,000 ohms between Y and Z.

In these illustrations one side of the pick-up is shown as going to GB –. This is straightforward when battery bias is used. It is also applicable in those mains receivers where the biasing arrangements are provided

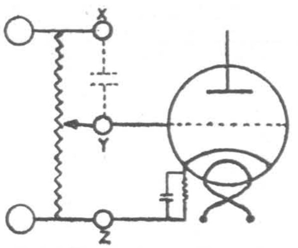

FIG. 47.—Potentiometer volume control with mains valve automatically biased.

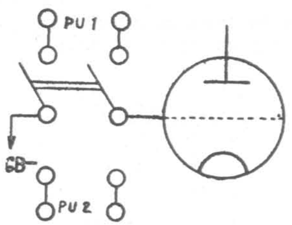

FIG. 48.—Simple change-over switch for two pick-ups.

for in the A.C. mains unit. When, however, automatic bias is obtained by means of a resistor in the kathode lead the connection reduces to that shown in Fig. 47. But it should be noted that if a D.C. mains receiver is used, the pick-up and volume control must be isolated from the mains either by the insertion of a transformer or by putting a 2 mfd condenser in each lead to the set. In this case an additional resistance shunted between the set sides of the condensers is required, so as to permit the bias to get to the grid.

Before we go on to consider the actual connections to the amplifier, it will be convenient to describe one or two switching arrangements to change over from one pick-up to another. At one time it was customary to use a simple double-pole double-throw switch as shown in Fig. 48. This, however, was not really satisfactory since it meant that whilst the switch was being thrown over the grid of the valve was free; this not only resulted in a noisy hum, but also did damage to the valve by depriving it of bias for an instant. In any case, of course, a single-pole switch would have done just as well, one end of each pick-up being permanently connected to bias. A better arrangement, using a single-pole double-throw switch, is shown in Fig. 49. Here the pick-ups are connected in series and one or other is shorted out when the switch is thrown over. In the central position both are in circuit and if a volume control is connected across each pick-up, before the connections are taken to the switch, the output from the two pick-ups can be mixed. There is a simpler method of arranging this, as we shall see. But if only a pure switching arrangement is required this series method is completely satisfactory; the change-over is effected without noise or hitch.

Another way of connecting two pick-ups is by means of a "fader" as shown in Fig. 50. Here B is a centre-tap in the resistance AC and the slider travels over the whole resistance AC. When it is in the section

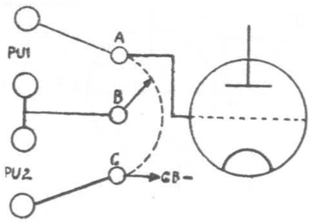

FIG. 49.—Improved switching for two pick-ups.

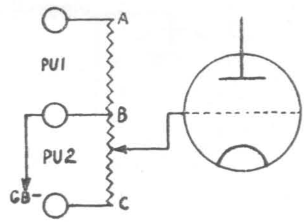

FIG. 50.—Fader for two pick-ups.

AB, pick-up No. 1 is in circuit; when in the section BC, pick-up No. 2 operates; at the point B both are dead. Unfortunately, satisfactory faders of suitable total resistance are not easy to obtain; usually one finds that when pick-up No. 1 is playing there is always a slight residue from No. 2 and vice-versa. In many ways the mixing device shown in Fig. 51 is preferable though it involves two potentiometers, and if the maximum flexibility is to be retained, two independent controls. Any desired mixture can be obtained with this arrangement and in addition the condenser device previously described can be used.

At first sight it might be thought that switching arrangements similar to those already described could be used for changing the L.F. amplifier over from radio to gramophone. Thus, in the case where the gramophone output, whether from one or more pick-ups, is to be switched in to the grid circuit of an L.F. valve, we might expect to have an arrangement such as Fig. 52, corresponding to that shown in Fig. 49. But this would be wrong. It would work all right on radio, but the biassing of the L.F. valve following the switch would be all wrong on gramophone. The reason is that all the H.T. currents from the earlier valves would have to pass through the pick-up coil on their way back to H.T. – and, apart from the deleterious effect on the pick-up, the voltage drop in the pick-up coil would give the L.F. valve a positive bias counteracting the negative bias provided by the resistor in the cathode lead. A similar objection holds to the mixing arrangement corresponding to Fig. 51. On the other hand, it is possible to devise a fader arrangement corresponding to Fig. 50. This is shown in Fig. 53. Here the part AB of the fader may be either the grid leak in a resistance-capacity coupling or may be connected across the secondary of an intervalve transformer, in which case it should have a resistance value of 500,000 ohms. One of the commonest forms of switching, at least among amateurs, is that shown in Fig. 54, in which the grid connection

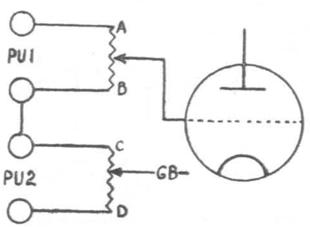

FIG. 51.—Mixer for two pick-ups.

of the L.F. valve is transferred from radio to gramophone by a single-pole double-throw switch. This has the disadvantage of breaking the grid circuit instantaneously and even with the snap switches now available may give rise to a certain amount of noise. From this point of view, a better arrangement is that shown in Fig. 55 in which the make-and-break switch for gramophone is operated by the shaft of the pre-detector volume control of the radio set in such a way that the pick-up is only in circuit

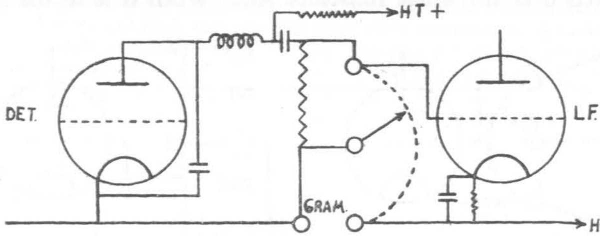

FIG. 52.—This switching arrangement corresponding to Fig. 49 will not work. On gramophone the L.F. bias is upset.

when radio is cut down to the minimum; or, alternatively, it may be ganged to an aerial to earth shorting switch. The disadvantage of this arrangement is that the preceding radio circuits are in effect shunted across the pick-up and thus constitute a load which may have untoward effects on the pick-up response. It should also be noted that if the pre-detector volume control is operated independently of this make-and-brake switch, this control and the volume control used in conjunction with the pick-up may together be used as mixers; but in this case the pick-up acts as an additional load on the radio circuits and vice-versa. Another arrangement of similar kind which is sometimes used is that shown in Fig. 56. Here the pick-up is inserted with a shorting switch at the foot of the grid leak in a resistance capacity coupling; in this case the grid leak is in series with the pick-up, and the preceding components are shunted across both. Even more complicated arrangements are sometimes used in commercial receivers; indeed, in some of them it is something of a puzzle to determine how the pick-up signal ever gets to the grid of the valve at all! Most of these arrangements, however, are subject to the grave disadvantage of putting a queer load on the pick-up which perhaps accounts for a goodly proportion of the bad quality one hears. The purist will probably always prefer the straight-forward arrangement shown in Fig. 54 except that he would no doubt introduce a grid decoupling resistance as at R in Fig. 57 and to safeguard the valve from loss of bias he might also put in a high resistance (say ½ or 1 megohm) as at S.

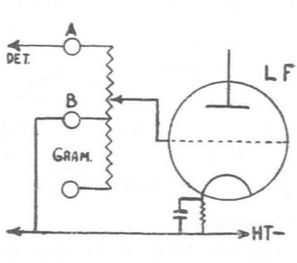

FIG. 53.—This fader, corresponding to FIG. 50 is satisfactory.

When the pick-up output is to be switched on to the grid of the detector it is necessary, besides taking care of all the points so far discussed, to arrange for the appropriate bias to be applied to the detector valve to convert it into an L.F. amplifier. When battery bias is being used the matter is simple: one only need connect one of the pick-up output leads to a suitable tapping on the grid bias battery, the positive end of the battery of course being connected to H.T.—. A similar arrangement is possible when the receiver obtains its bias from resistors in the negative lead of the mains unit. Grid decoupling may also be introduced in a quite straightforward manner as shown in Fig. 58.

If automatic grid bias is obtained by means of a resistor in the cathode lead and grid rectification is used, the arrangement must be such that the bias is only applied when the set is switched over to gramophone. The

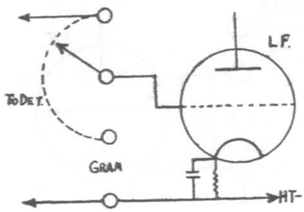

FIG. 54.—Common form of switch from radio to gramophone.

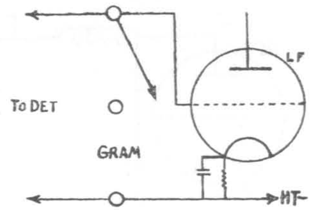

FIG. 55.—Make-and-break switch ganged at foot of pre-detector radio volume control.

straightforward way to achieve this is to use a double-pole switch in such a way that the bias resistor is shorted when the set is on radio. This is shown in Fig. 59. A little consideration, however, will indicate that by rearrangement of the grid leak the necessity for this shorting switch can be avoided. The biasing is due to the fact that the H.T. current passing through the valve causes a drop of volts in the cathode resistor ; the actual cathode is thus at a positive voltage relative to the H.T. – line and if the grid is in metallic connection with the latter and no D.C. current is flowing in any resistance between the two, then the grid is at H.T. – potential and thus has a negative bias relative to the cathode. In Fig. 60 there is external metallic connection between grid and H.T. – only when the pick-up is in circuit ; on radio the metallic connection is to the cathode direct. Thus in this case there will be a negative bias on gramophone and no bias at all on radio. Grid decoupling on gramophone is also shown.

The change over of an anode bend detector likewise presents no

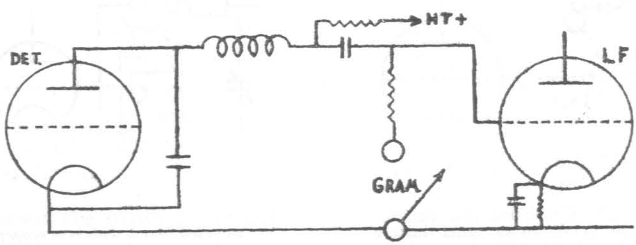

FIG. 56.—A modification of the arrangement in FIG. 55.

difficulty when battery bias or "mains unit" bias is used, the only necessary precaution being to take the low-potential end of the pick-up to a suitable G.B. – as in the case of the grid detector. When " cathode " bias is used a shorting switch to reduce part of the biasing resistor when on gramophone may be incorporated. Since the valve will pass more anode current when the bias is reduced, there will be a tendency for the H.T. voltage at the anode to be reduced on gramophone, as already noted, owing to the increased voltage drop in the resistances used for H.T. decoupling. This reduction of voltage will be mitigated by the use of a potentiometer feed of H.T. to the anode circuit, but it is desirable to avoid it in the interests of good quality reproduction. This can be done by arranging for the change-over switch to short out part of the H.T. decoupling resistance when on gramophone. A suitable circuit arrangement is shown in Fig. 61. Here, it will be noted, the shorting of the bias resistor has been

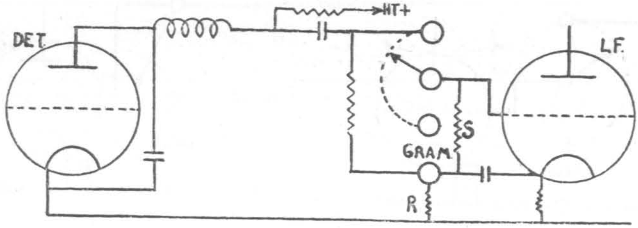

FIG. 57.—The purist's switch with grid decoupling R and bias safeguard S.

obviated by the method of connection of the grid decoupler R; in this circuit the bias resistor R_1, only affects the bias on radio, the metallic connection to the grid then being through the tuning coil (not shown). R_2 is a voltage stabiliser for anode volts and acts with R_3 and R_4 as a potentiometer. Resistance capacity coupling to the following valve is shown, but similar arrangements apply with transformer coupling. Note that in this case, as in Fig. 60 it is not possible to introduce a resistance (S) between grid and decoupling resistance so as to have a grid load in all positions of the switch as was done in Fig. 57; this would render nugatory the artifice employed to avoid the use of a shorting switch to alter the bias.

There is one other type of detector that should be considered for although it is not used commercially in this country as yet it has so many advantages over other types that it is likely to take precedence over all others for quality sets and particularly superheterodyne receivers. This is the diode grid rectifier. Two forms of it are shown in Fig. 62; (*a*) and (*b*)

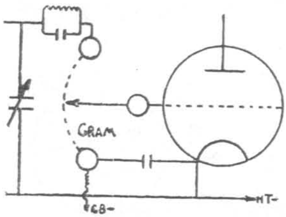

FIG. 58.—Converting grid detector to gramophone, using battery bias or bias resistor in negative lead of H.T. mains unit.

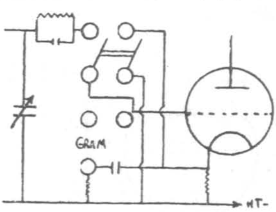

FIG. 59.—Converting grid detector to gramophone with bias resistor in cathode lead short-circuited on radio.

both are effective but, on the whole, the (*b*) arrangement seems the better. In both types no H.T. is used and, while in both the anode should technically be connected to the grid, it does not in the (*b*) case seem to make any difference if it is disconnected altogether. As may be anticipated, rather a complicated arrangement is needed to transform a detector such as this into an L.F. amplifier for use on gramophone. We have to supply both H.T. and bias, as well as an anode resistance. The arrangements

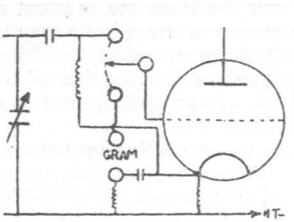

FIG. 60.—Arrangement of grid detector to avoid necessity for shorting bias resistor on radio.

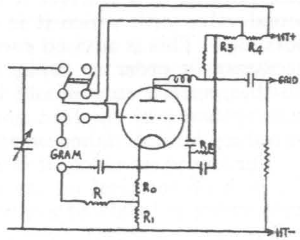

FIG. 61.—Switching anode bend detector, altering bias and maintaining stabilised H.T. voltage.

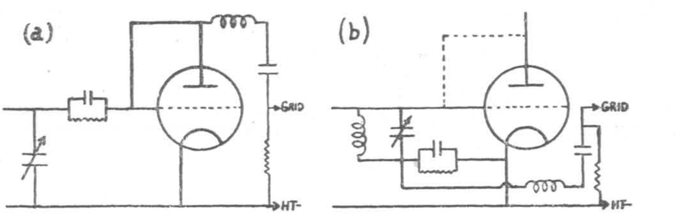

FIG. 62.—Two types diode grid rectifier.

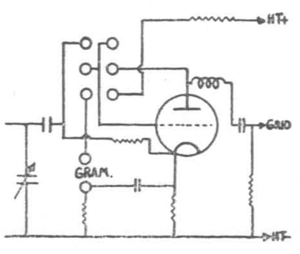

FIG. 63 (*a*).—Switching for first type of diode, introducing H.T. and bias.

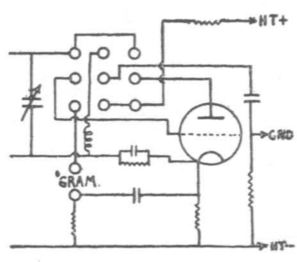

FIG. 63 (*b*)—Switching for second type of diode.

shown in Fig. 63 (*a*) and (*b*) appear to be the simplest possible.

Finally, it should be said that when a radio to gramophone switch is incorporated in a receiver it is well to place it as near as possible to the actual valve with which it is concerned, so that the leads are as short as possible. This is advised even though an extension of the spindle may be necessary in order to bring the control knob to an accessible position. Further, special care should be taken with regard to the position of the gramophone pick-up lead going to the switch. A straggling lead may introduce hum or other unwanted reaction effects.

For this reason, too, it is a wise precaution, in connecting up between the pick-up terminal on the receiver and the change-over switch, to use wire which is insulated and then covered outside with metallic sheathing which can be earthed. Similarly the leads from the pick-up itself to the receiver should preferably be of twin, sheathed flexible cable, the braiding being earthed. Two types of sheathed cable are available for the purpose : the inferior kind is aluminium covered and is normally used for car lighting systems ; a much better type has a braiding of woven copper. If the distance between the turntable unit and the receiver itself is considerable, say more than a yard or so, these precautions are very necessary and in addition it will probably be necessary either to put a high resistance or perhaps better still a 1 : 1 transformer between the pick-up terminals and the change-over switch in order that what is in effect the grid terminal of the first valve need not be extended to a distance outside the set. Remember that the grid of a valve is very sensitive to hum and other disturbing noises ; and also, in any connections of this kind take particular care not to fall into any of the pitfalls already illustrated and rob the valve of its proper bias.

SOME GRAMOPHONE QUERIES SIMPLY ANSWERED.

SOUND-BOXES.

Q. What is the cause of a gramophone squeaking on certain notes?

A. It may be due to maladjustment of the stylus pivoting, or to perished or hardened gaskets. The squeak may also be due to a fault in the horn. As to that one could only determine by careful examination.

Q. Can phosphor bronze be used successfully in the manufacture of sound-box diaphragms?

A. No. For its stiffness it is too heavy. Phosphor bronze as well as nearly every material under the sun has been used at one time or another for making diaphragms.

Q. Would a sound-box having a large diaphragm be suitable for use with a bifurcated horn the overall length of which (including tone-arm) is 14 ft., and give better results than a small diaphragm box.

A. No; on no account must a large diaphragm be used. A diaphragm 43–50 millimetres in diameter is capable of giving a good bass response down to the cut-off of the horn. A larger diaphragm would give a very uneven treble. Large diaphragms are only justified with small horns where the bass response has to be strengthened by diaphragm resonances.

Q. When a sound-box or pick-up has been adjusted to give good quality reproduction how is it possible to tell whether record wear is likely?

A. To tell whether record wear is likely without first actually wearing a record requires a certain amount of experience. There are two signs which can be depended upon as indications of excessive record wear. They are:

(1) the needle chatters in the groove. By this we do not mean that it sings a tune but that it "jazzes" about.

(2) a fibre needle point will break down.

Q. Is there a suitable method which an amateur can apply for cutting mica diaphragms?

A. This may be successfully accomplished by the following method: Tightly clamp the mica to be cut between two old diaphragms, or waste pieces of mica, and place them on the end grain of a circular block of wood the diameter of which is exactly the same as the diaphragm to be cut. Procure a metal sleeve whose internal diameter is again the same size as the diaphragm required, and grind it to a sharp edge externally. Then press the sleeve over the mica and a block of wood. In other words, the diaphragm would have to be stamped out.

Q. (*a*) Is phosphor bronze a suitable material for making the back plate of a sound-box?

(*b*) Is it better to make the stylus bar in one straight strip and bend the end over, or stamp it out in one piece?

A. (*a*) Yes.

(*b*) Either method is satisfactory.

Q. Can metal diaphragm sound-boxes be tuned if fitted with plain pivots?

A. Not readily, only by altering the gasket pressure, carefully adjusting the pivots and by reducing, if possible, the mass at the stylus-diaphragm joint.

Q. Is a sound-box likely to deteriorate by playing dance records?

A. To preserve the tuning of a sound-box it would be better to use a separate box for dance records. Heavy records of this type will tend to tire the diaphragm and tend to destroy the tuning of the sound-box.

Q. A careful inspection of my mica-diaphragm sound-box revealed that the mica was cracked. The crack starts at the centre and extends a little way beyond the wax round the stylus joint. Apart from the tone seeming rather lifeless I can detect no aural difference. Is it advisable to fit another diaphragm?

A. Yes: otherwise the crack will eventually extend right across the diaphragm and high and low note loss and distortion will result.

TONE-ARMS.

Q. Can a uniform bore tone-arm ½ inch in diameter and 12 to 15 inches long be coupled to an exponential horn without impairing the reproduction?

A. A uniform bore of more than 12 inches length in the tone-arm has a tendency to make the deepest bass rather "peaky." With a very large horn this may be an advantage since the recording falls off at very low frequencies.

Q. What is the ideal length for a tone-arm, or pick-up arm, from needle point to back pivot?

A. There is no ideal length. The longer the better within practical limits.

Q. Which is the more important to obtain good reproduction on a gramophone, the tone-arm or the horn?

A. Both are important for good reproduction. If one has a tone-arm of good design coupled to a horn of bad design, results are bound to be inferior, and the same remark applies, though perhaps not to the same extent, when these conditions are reversed. Strictly speaking, the horn, the tone-arm, the sound-box *and* the needle should be in "tune" to obtain ideal results.

Q. Is the "Crescent" tone-arm of suitable taper for use with a 6 ft. exponential horn?

A. As this tone-arm is of fairly small bore and slow taper the combination should work well.

Q. I am contemplating the construction of a large exponential horn. Will you please say which type of tone-arm you advise me to use in conjunction with it: one with a narrow bore or a large bore tone-arm?

A. The answer really depends on the sound-box; but with sound-boxes now available a narrow bore tone-arm with a slow rate of taper is very much better than one with a large bore. A tone-arm in which the first 5 or 6 inches of bore is parallel would be better still. You would get a cleaner and deeper bass, and also more volume.

HORNS.

Q. What size of horn would be required to reproduce the whole range of audible frequencies?

A. A horn at least 40 ft. long with a mouth opening of something like 15 ft. square would be required.

Q. What is suitable material to use in the construction of an internal horn for a gramophone?

A. Terne-Plate. This is sheet iron one side of which is lead-coated. It is easier to work than zinc, and has a much lower resonance than tin. It has a number of advantages over ply-wood, not the least of which is that the joints can all be made firm by soldering. Do not use a gauge of thickness less than No. 22; 18 gauge would be better.

Q. (*a*) Would there be any appreciable difference in tone between folded horns of circular and square section?

(*b*) Would it be an advantage to bifurcate the horn?

A. (*a*) No, provided care is taken to avoid drumminess in a square section.

(*b*) Yes, if properly done. The principles of bifurcation are too long to be explained here. Put briefly, the advantage is that in a bifurcated horn the inside and outside curves of a bend can be made more nearly equal than in an ordinary folded horn. Also, energy lost through cross-reflection will be of higher frequency. The main principle of design is that the sum of the areas of a bifurcated horn at corresponding joints in the two sections (*i.e.*, at the same distance from the point of bifurcation) should be equal to the area of the straight horn the performance of which it is desired to imitate. Do not forget that bifurcation is only resorted to in order that the horn made be folded without undue bad effects. The response of a straight horn is usually more nearly perfect than that of a folded horn.

Q. What is the best ratio of expansion for an exponential gramophone horn?

A. There is no *best* rate of expansion. The whole subject has been dealt with in the Wilson-Webb book "Modern Gramophones and Electrical Reproducers," but it takes up thirty pages.

Q. What is the explanation of the word "Exponential"?

A. In mathematics an "exponent" is the same as an "index." Thus in 2^3 (two cubed $= 2 \times 2 \times 2 = 8$) the 3 is the index or exponent. In an exponential horn the diameter of a section, y, is given by a formula of the type $y = a^{bx}$, where a and b are constants and x is the distance of the section from the throat. Here bx is the exponent and since x is variable, a^{bx} is known as an exponential function of x.

Q. In designing a gramophone with a four foot exponential horn should the tone-arm follow the same rate of taper as the horn?

A. It would be better if the tone-arm followed the same rate of taper up to about 6 inches from the sound-box end, when it would be an advantage to have the remaining portion of parallel bore.

Q. What is the minimum length of an exponential horn that would reproduce effectively the lowest and highest notes that are recorded?

A. A horn 25 ft. long would be needed to reproduce *all* the recorded frequencies.

Q. Would an extra 5 ft. added on to the length of a 10 ft. exponential horn, which is used in conjunction with a 555W. moving coil unit, make a decided difference to the low notes?

A. It is doubtful; the cut-off would only be six semi-tones lower. An extra 10 ft. would, but ....

Q. Is the formula for an exponential horn (given in the Wilson-Webb book) applicable to horns of square section as well as to horns of circular section?

A. Yes: providing a square of equivalent area to a given circle is adhered to.

Q. Is the length of the tone-arm taken into account when working out the contour of an exponential horn?

A. Yes: but it is better to get a tone-arm of small diameter and slow taper before making any calculations for the horn. The small end bore of the horn must correspond exactly to the large end bore of the tone-arm, and the rate of taper should not be greater than the initial part of the horn.

Q. I would greatly appreciate your advice about a problem in exponential horn design.

Working with Mr. P. Wilson's formula given in *The Gramophone* :—

$$\log y = \log yo + mx$$

(m being 110/4840 = ·02275) I obtain

Length at	0 inches	=	·38	inches throat diameter.
,,	1 ,,	=	·5269	,, ,, ,,
,,	2 ,,	=	·5552	,, ,, ,,
,,	96 ,,	=	76·38	,, ,, ,,

This last diameter does not agree with the approximate sizes stated in "Modern Gramophones and Electrical Reproducers" by Mr. P. Wilson and Mr. G. W. Webb—that a cut-off of 100 cycles requires a horn 8 ft. long and 36 in. mouth diameter.

Can you point out where I have tripped up?

A. The figure 4840 given in *The Gramophone* was based on an assumed velocity of sound of 1,100 ft. per second. But according to temperature the velocity may rise, and in "Modern Gramophones" the one taken as representative of normal conditions was 1,130 feet per second. Taking the former value, the formula on page 97 of "Modern Gramophones" gives

$$m = \frac{f}{\cdot 3665 \times 1100 \times 12} = \frac{f}{44 \times 1100} \text{ approximately}$$

$$= \frac{f}{4840}$$

Taking the latter value—

$$m = \frac{f}{\cdot 3665 \times 1130 \times 12} = \frac{f}{4935}$$

Taking f = 100 in both cases :—

Case (1) :—

$$m = \frac{1}{48\cdot 4} = \cdot 020661$$

$$\log y = \log \tfrac{1}{2} + 96\,m$$

$$= \bar{1}\cdot 69897 + 1\cdot 98347$$

$$= 1\cdot 68244$$

$$\therefore y = 48\cdot 1 \text{ or } 4 \text{ ft.}$$

You will find, however, that

$y = 42$ inches when $x = 93$ inches.

You see the diameter at the big end increases very rapidly.

Case (2) :—

$$m = \frac{1}{49\cdot 35} = \cdot 020263$$

$$\log y = \bar{1}\cdot 69897 + 96 \times \cdot 020263$$

$$= \bar{1}\cdot 69897 + 1\cdot 94525$$

$$= 1\cdot 64422$$

$$\therefore y = 43 \text{ inches}$$

The two calculations make a little difference, but not so much as to affect the general statement on page 103 of the book. The discrepancy arose simply because you assumed a cut-off at 110 cycles instead of at 100 cycles. 10 cycles at that position of the scale is a very big difference of pitch. Naturally, in those circumstances, you get a very big difference in the size of the opening of an 8 ft. horn. As mentioned earlier, the diameters increase very rapidly at the open end.

Q. It is said that the original Mark X gramophone has a cut-off of about 82 cycles. Can you tally this statement with question 93, line 13, page 468 in the March 1930 *Gramophone* : " a bass cut-off of a 100 cycles requires a horn 8 ft. long and 36 in. mouth diameter " ?

A. In a horn there are two important factors : the rate of taper and the diameter of the mouth. The rate of taper determines the cut-off frequency of the sound transmission along the horn. For exponential horns, this cut-off is quite sharp. For any given rate of taper there is a definite diameter of mouth which gives a minimum reflection at the open end for *frequencies above the cut-off* determined by the rate of taper. If the horn is not carried far enough to have this mouth opening, resonances in the horn become more pronounced, particularly at frequencies near the cut-off.

To obtain proper bass with a horn, a really long horn with a large opening is required. There is no shadow of doubt about this. Clearly, however, this may be inconvenient. The question then arises as to which is the best compromise : (1) To increase the rate of taper so as to accord with the convenient size of mouth opening and so establish a higher cut-off frequency, thereby neglecting the deeper bass ; or (2) to keep a small rate of taper and stop the horn at the convenient size of mouth opening, thereby keeping a certain amount of bass, but making it peaky.

Obviously the answer to this question depends on the amount of resonance which an individual ear will tolerate in comfort. In practice one finds that a considerable amount of bass resonance can be tolerated, and therefore, although theoretically the best relation between mouth opening and rate of taper is such that at the mouth the slope of the horn to the axis is about 42°, it is quite good practice to reduce the rate of taper (and increase the length of horn) until the slope at the mouth is not more than about 36°. With smaller angles of slope the resonances become sharper and more pronounced, so that the advantages of a small rate of taper and a long horn become lost and the tone tends to become muffled and backward.

When one compares a horn with a compromise of this sort to one with the same rate of taper continued to the optimum mouth opening, the difference is quite appreciable in the general smoothness and breadth of tone. But it is fairly certain that few people would detect this defect in the compromised horn if they were not able to make a direct comparison.

Q. Would it be satisfactory to set an internal horn in Plaster of Paris ? The authors of " Modern Gramophones and Electrical Reproducers " mention that the experiment has been tried.

A. It is quite possible to set a horn in plaster. The effect would be to clean up the tone, but might also limit the range in the bass register as compared with a horn made of a more resonant material. This would be the case if wall resonances of the latter were arranged to give the effect of an extended bass. On the whole, with a small internal horn it would be better to make it out of Terne-Plate or Papier Maché.

Q. A cabinet gramophone I am constructing will take a 5 ft. (130 cycles) horn, but it is not large enough to permit the mouth opening (about 2 ft. diameter) required for a horn of this length. Will I get satisfactory results if I make the taper of the horn as for one of 64 cycles, extending the taper for the last foot or 18 inches to the size of mouth allowed by the cabinet; about 22 in. by 17 in.? Alternatively must I make the horn as first stated and be content with the smaller opening?

A. Probably your best choice is to make the horn as for a transmission cut-off of 100 cycles and stop it at the largest diameter your cabinet will allow. A 64 cycle taper will give you too slow a taper for the mouth opening.

Q. I have worked out an exponential horn with a 96 cycles cut-off, and I find that at 24 inches diameter the angle the horn's side makes with its axis is less than 36 degrees. Of course, when the horn is modified and the length increased until at 8ft. 6 inches, the diameter is 24 inches the angle is still less. Could you tell me the method of reducing the taper of a horn and increasing the angle at the mouth at the same time?

A. It is impossible to decrease the rate of taper and at the same time increase the angle of the mouth of the horn without also increasing the length.

Q. Could you advise me as to the easiest way to join the edges of a metal exponential horn, square in section. Can it be done without a great knowledge of metal work?

A. If the horn you intend making is of the folded type you may experience some difficulty in joining the sides, and it would perhaps be cheaper and more expedient to let your local tinsmith do it. If, however, the horn is a straight one probably the best method is to clean and "tin" all the edges, make some thin angle strips, "tin" these and sweat the angles on to the joints, afterwards cleaning the insides of the joints and running solder into the corners.

Q. I have been experimenting with a 10 ft. folded horn, but instead of using the true logarithmic formula, where the unit of length is constant, I designed it with a constant *decreasing* unit of length. The result was a slight increase in bass with a considerable loss of forward tone and a greater tendency to peakiness. This formula was obviously a poor one, as in the extreme case the unit of length becomes *nil*, while the expansion theoretically continues. To strike a medium between the two formulae I have in mind a third one in which the unit of length decreases *not constantly* but with a logarithmic *decreasing difference*. This makes the unit become practically constant again towards the mouth, but as its curve lies entirely inside that of the true logarithmic (assuming neck, mouth and length to be the same) it greatly facilitates folding. I should be grateful for your opinion as to what effect the last formula would have in comparison with the true logarithmic in

(*a*) Bass and treble.
(*b*) Balance of whole range.
(*c*) Definition and forwardness.
(*d*) Effect on life of needle in difficult passages.

A. We cannot really express a definite opinion about your proposed formula. It is a matter for experiment. The folding will have the biggest effect of all, but in a straight horn one would expect:—

(*a*) Deeper bass, more peakiness, but less strong.
(*b*) The balance would be much the same.

(*c*) Tone would not be as forward as with a true logarithmic horn.

(*d*) No appreciable difference.

NEEDLES AND NEEDLE SCRATCH.

Q. Is it possible to exclude needle scratch when playing records on either a gramophone, or through an electric amplifier, without impairing the reproduction?

A. No: if one is to reproduce high notes adequately from gramophone records one must reproduce a certain amount of surface noise also. The two things go together and cannot be separated. It is quite easy to abolish surface noise, but it simply is not worth while to do so if one is interested in obtaining good reproduction. On the other hand surface noise can be considerably reduced simply by avoiding high note resonances.

Q. When a needle socket of a sound-box is only cut to take round needles is it advisable to use an adaptor for fibre needles?

A. No: to get the best results with fibres it is essential to have a specially made or tuned sound-box.

Q. Is there any advantage in storing Burmese Colour, Electrocolor or Fayotone needles in a dessicator or "dry air bowl"?

A. Very little; but there is no disadvantage.

Q. Is there any advantage in using soft-tone needles for the first two or three times a record is played, before using medium needles

A. There is no advantage. If fibres are used it is sometimes an advantage to clean out the grooves with a fine steel needle first.

RECORDS AND RECORD WEAR.

Q. Is it beneficial to clean records with olive oil?

A. No: olive oil is not very volatile, and the result is that records so treated retain grease to which dust and dirt easily adhere. If records have already been washed with olive oil, rub them over with white vinegar and dry thoroughly with a clean cloth. A suitable method of cleaning records is described on page 62. But do not use any cleansing mixture unless it is absolutely necessary.

Q. Is a gramophone designed for pre-electric records likely to damage the grooves and wear out electric recordings prematurely?

A. Yes: the reason is that the older gramophone had only to respond to a short range of notes. Deep bass was not recorded. For electric records absence of response in the bass causes a reaction effect on the needle, and thus damages the records. This is one reason why portable gramophones cause relatively more record wear than instruments with large acoustic systems.

Q. After playing a record of *Liszt's Second Hungarian Rhapsody* by the Philadelphia Symphony Orchestra, wear became so acute that the record had to be relegated to the dustbin. The instrument used is of the pedestal type. Please explain the cause.

A. This record is one of the most difficult records to play with steel needles without wear. To do it well will require not only correct alignment, a level instrument and a freely moving tone-arm, but a very efficient sound-box and a horn with a very low cut-off, which few pedestal gramophones have. If this is the only failure there is little cause to worry. In any case, to alter the alignment in a gramophone is not an easy matter for an amateur to attempt.

Q. Does a damp atmosphere affect records?

A. Yes: both excessive damp and heat tends to warp records, as well as to create blisters. Records should be stored in a cool, even and dry atmosphere.

Q. How many times may a record be played with steel needles before it is ruined for use with fibre needles?

A. A great deal depends on the particular record, and on the particular instrument it is played on. If the disc is heavily recorded, then, even on a gramophone possessing good alignment, and a freely moving tone-arm, two or three playings will ruin it for fibres. A lighter recording will stand more playings. If, however, the alignment of the instrument is bad then one playing is sufficient to render the record useless for fibre playing.

Q. I find that by sharpening Electrocolor and Burmese Colour needles so that the point is stubby (nearly a U shape) I get better volume. Will you please tell me if this type of "point" is likely to wear records unduly?

A. Although record wear will not be excessive, we do not advise you to continue sharpening needles in this way. You are sacrificing quality for quantity. The point will never really get down to the bottom of the grooves, and consequently reproduction will suffer.

ALIGNMENT.

Q. What is the smallest circle to work to when using the Wilson Alignment Protractor?

A. The smallest circle is one with a radius of 2 inches.

Q. When altering the position of the tone-arm or motor in order to reduce the error of alignment, is it better to have the largest error on the inside of the record?

A. No. It is most important that the error here should be small. If a fairly large error is inevitable arrange matters so that the largest error is on the outside edge.

Q. I have been trying a different motor in my gramophone but cannot get this in quite the same position as my previous one. The question I have to raise is regarding needle track alignment. I have obtained the following figures with the Wilson Protractor: at 2 inches error is 1°, at 3 and 4 inches is 0°, at 5 inches error is plus 2½°, at 6 inches error is plus 5°. The offset is 3 inches, and the distance between tone-arm pivot and centre of spindle is 8½ inches. Do the above figures show a satisfactory state of affairs?

A. The alignment errors you give are well within reasonable bounds, and the fact that they are smallest towards the inside of a record is all to the good.

Q. Having bought a Wilson Protractor, I am puzzled how to use it. Is there any rule to decide which number, 1 to 6, is to be placed against the turntable spindle? Should the pointer be kept on the right hand side of the sound-box? On my instrument when Fig. 3 is against the spindle and the needle on 1½ (line YZ) the lines on the pointer are not parallel with the face of the sound-box, and to set them so that they are parallel, the pointer would need to come on the other side of the needle, *i.e.*, on the left side of the sound-box.

A. If you wish to take the alignment error on the outside edge of a record, then set Fig. 6 (line AB) against the turntable spindle and place the needle on the figure 0 (line YZ). If the pointer comes up against the needle point without the lines being parallel to the sound-box face, try the needle point on figure 1 (line YZ) and place figure 5 (line AB) against the turntable spindle. You will thus still be taking a reading at 6 inches radius from the centre of the record. If you wish to take the reading on the inside of a record, place figure 2 (line AB) against the spindle and the needle on figure 0 (line YZ) and proceed as before. It is immaterial for the measurement of error where you place the needle on the line YZ. With some pick-ups it is difficult to set the moving arm of the protractor owing to the design of the pick-up casing; there is no straight face to which to set the parallel lines on the moving arm. In such cases you will have to visualise a straight line through the needle and then use the protractor in the ordinary way.

Motors.

Q. Does it require a stronger motor in a gramophone to use fibres successfully?

A. It depends on the reserve power of the existing motor. If the speed perceptibly wavers about half way through a 12 inch record when using fibres, and will yet play the same record throughout using steel needles, the motor has not enough power reserve. The reason is that the surface friction is greater with fibres than with steel.

Q. When playing organ records there is a distinct wavering in pitch throughout the discs. Military band records, vocal records and speech records are perfect as regards pitch. In order to ascertain whether the records were faulty new ones were purchased, with the same result. Is it due to a faulty motor?

A. It is most likely that the motor is at fault. Either it is not pulling properly or it has not the reserve of power necessary. Organ records often show up a deficiency of strength in the motor, or defects in governing owing to the surging nature of the music.

Q. If a gramophone turntable is badly out of truth, will it affect reproduction or record wear?

A. If the turntable does not rise and fall more than $\frac{1}{32}$ of an inch there is little cause for worry. But on the other hand, if it is badly out of truth, a wavering in pitch and probably premature record wear will result.

Q. I recently purchased an electric gramophone motor, but found when fixed in position and switched on that it caused a rumbling noise in the loud-speaker. In an attempt to cure the trouble I connected a centre-tapped condenser across the mains with the centre tap connected to the motor frame as instructed by the makers. This had no effect whatsoever. Can you help me to solve the problem?

A. Some electric motors we have tested are practically incurable of this trouble. We find it difficult to give any certain cure without knowing the position of the motor in relation to your pick-up. The motor should be fixed in such a position on the motor board so that the armature and stator are as far away from the pick-up when playing as is possible. If your pick-up leads are not screened try screening them by using metal-covered wire. Try connecting the potentionmeter volume control (across the pick-up) with one end of the resistance element connected to the grid of the valve, the other end connected to earth through a 2 mfd. condenser, and with the slider connected to grid bias negative. If these suggestions have no effect the only alternative is to completely screen the motor.

Q. Will you please say if it is harmful to change the speed of a gramophone motor for occasional records?

A. So long as the speed regulator is moved carefully no damage will be done. But it is unwise to alter the regulator by a sudden movement when playing a record. This would sprain the governor springs.

Q. I should be obliged if you will advise me on the noisy running of my gramophone motor. This has suddenly developed a very loud whirr as though caused by a ratchet. I have thoroughly lubricated the moving parts without mitigating the trouble. Can you diagnose the complaint?

A. From the particulars you give it seems that the whole of the trouble lies in the adjustment of the governor. Probably there is too much play between the governor spindle and the end bearings, or possibly one of the bearings has slipped, with the result that the governor worm is too deep in mesh with the worm wheel. Re-adjust the eccentric end bearings so that there is a very small amount of play between the end bearings and also between the teeth of the worm wheel and the thread of the worm. Then apply some Three-in-One oil to the governor pad and let the motor run for a while. If the pad has become too hard it will need softening or, better still, replacing.

MISCELLANEOUS.

Q. How can one make use of a wireless set for the electrical reproduction of records without making any substantial internal alterations?

A. The simplest method is to use an Igranic switch adaptor. This fits into the valve holder, and the valve is then placed into the adaptor. A switch fitted to the adaptor enables one to switch in the pick-up without removing the adaptor from the valve socket.

Q. I have just purchased a Meltrope pick-up. As I may find it necessary to use an input transformer, would you advise me to use an R.I. Hypermu transformer as per the instructions issued with the pick-up, or to use a tone control circuit similar to the one published in the September 1930 *Gramophone*?

A. If you find it absolutely necessary to use an input transformer, then we advise you to follow out the instructions given with the pick-up. We do not, however, recommend the use of any tone corrector device with this pick-up, apart from a ·0015 mfd. condenser, which may be connected *across* the pick-up should you wish to strengthen high note response.

Q. Is it possible to work a pair of headphones *direct* from a pick-up?

A. Yes: it is just a matter of matching the resistance of the headphones to that of the pick-up.

Q. I am contemplating reproducing my records electrically, using a two valve amplifier, and a pick-up. I intend to convert the horn of a medium size pedestal gramophone by fitting a moving-iron speaker unit on the tone-arm in place of the sound-box. Will this arrangement give a deeper tone?

A. A good deal depends on the amplifier design and the pick-up. With a suitable amplifier and pick-up the volume would certainly be greater and the tone more forward, but the bass would probably be peaky and muffled owing to the inability of the unit and horn to pass the really low frequencies. With a large horn and moving coil unit, however, this register would be very much improved.

Q. (*a*) Will you please enlighten me as to the reason why alternating current moving coil speakers are more expensive than the direct current models?

(*b*) Also what takes place when the signal leaves the loud-speaker terminals on the set for the loud-speaker itself in the case of an A.C. speaker and a D.C. speaker?

A. (*a*) The reason why A.C. speakers cost more than the D.C. type is because a mains transformer, a valve or metal rectifier and an electrolytic condenser have to be incorporated in the equipment to transform the mains voltage down to the required voltage and to convert the A.C. into D.C. to create the necessary magnetic field.

(*b*) The energy from the receiver is transferred to the speech coil of an A.C. speaker in exactly the same way as with a D.C. speaker. The only difference between the two types of speakers is as explained above, the conversion from A.C. to D.C. for the energising of the field coil.

Q. What is the advantage of using a rubber or cork turntable mat?

A. The only advantage is to minimise any risk of the records slipping on the turntable whilst playing.

Q. I wish to convert a small room into a sound-proof music room. Can you suggest any efficient method of doing this?

A. One of the cheapest methods is to line the walls and ceiling with Celotex board, and cover the door with a heavy curtain. A more efficient way would be to mount the Celotex on battens and stuff the space between with wood-wool, Cabot's Quilt, dried seaweed, or some such material.

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(*The figures refer to pages.*)

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