BBC

ENGINEERING DIVISION

MONOGRAPH

BRITISH BROADCASTING CORPORATION

No. 5

REPRODUCING EQUIPMENT FOR FINE-GROOVE RECORDS

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(DESIGNS DEPARTMENT, BBC ENGINEERING DIVISION)

FEBRUARY 1956

BRITISH BROADCASTING CORPORATION

FOREWORD

THIS is one of a series of Engineering Monographs published by the British Broadcasting Corporation. About six will be produced every year, each dealing with a technical subject within the field of television and sound broadcasting. Each Monograph will describe work that has been done by the Engineering Division of the BBC and will include, where appropriate, a survey of earlier work on the same subject. From time to time the series will include selected reprints of articles by BBC authors that have appeared in technical journals. Papers dealing with general engineering developments in broadcasting may also be included occasionally.

This series should be of interest and value to engineers engaged in the fields of broadcasting and of telecommunications generally.

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REPRODUCING EQUIPMENT FOR FINE-GROOVE RECORDS

SUMMARY

This Monograph describes a reproducing desk designed specifically for use in the BBC for the reproduction of fine-groove (long-playing) recordings at speeds of 45 and $33\frac{1}{3}$ r.p.m.

The authors describe the factors which led to a design rather more elaborate than that which would be needed for the straightforward reproduction of such recordings under domestic conditions.

It is pointed out that in the BBC it is comparatively rare for a fine-groove recording to be reproduced in its entirety but quite common for short excerpts to be used, often in quick succession. It must therefore be possible to find a passage quickly, and to commence reproduction on the chosen word or note at exactly the right moment.

This requirement makes it necessary to provide some means of locating the pick-up on the record and to employ some form of quick-starting device in order to reduce the time normally taken for a record to accelerate from rest. The modification of a commercial turntable to provide this latter facility and the steps taken to ensure that the output of the desk is muted until the record is up to speed are described in some detail.

In order to assist in locating the desired passage an optically projected scale has been provided but on fine-groove records it is not in general practicable, even with the scale, to arrange for the pick-up to be lowered into a particular turn of the spiral groove. The design is such, however, that a passage may be located exactly by rotating the record to and fro by hand whilst the pick-up is resting on it; a procedure much the same as that employed with magnetic tape. Not all types of pick-up can be used in this way, and this point had to be considered in addition to the usual requirements, in choosing a pick-up for this equipment. It is shown also that although in most respects the performance of a pick-up intended for professional use must be superior to that of one for domestic service, there are some points, notably output voltage and shape of frequency characteristic, where the requirements are less stringent.

The Monograph goes on to describe the general construction of the reproducing desk, and shows that in the interests of standardization an existing amplifier has been incorporated. It is shown also that, whilst the inside of the desk is inaccessible to the operator, access for maintenance is both easy and rapid and that installation is simple in that only one mains point and one programme input socket are needed for the installation of up to six desks in one studio.

1. Introduction

The equipment required for the reproduction of fine-groove records in a broadcasting service is much more elaborate and expensive than the kind that is normally used for replaying gramophone records in the home. This arises not merely because the broadcasting equipment is required to give a high standard of reliability and of technical performance in very onerous conditions of service, though these considerations do account for some of the differences. What perhaps even more markedly distinguishes the broadcasting from the domestic type of equipment in this field is that, in a broadcasting service, it is comparatively rare for a record to be played in its entirety. In most cases, and particularly with long-playing fine-groove records, only excerpts are required and it is essential to be able to start precisely at a chosen point in a recording and to do so at exactly the right moment. It is clearly impracticable to do this with a simple turntable and pick-up.

In practice the ease and speed with which these 'spotting' or 'editing' operations can be carried out may settle the amount of equipment and the number of operators that are required for the production of certain types of programme and it therefore becomes worth while to accept some additional cost of equipment in order to provide the appropriate facilities in a convenient form. This leads to the introduction of procedures and devices which have no counterpart in the domestic gramophone field.

The first part of this Monograph discusses the problems that arise in providing the editing facilities referred to and surveys in a general way the implications of the technical performance that is required. The second part of the Monograph describes the principal features of a new reproducing desk which, against the background of these considerations, has been developed by the Engineering Designs Department for the reproduction of fine-groove records in the BBC.

PART I DISCUSSION OF THE PROBLEMS

2. Editing Facilities

Fine-groove gramophone records are used in the BBC both as a means of providing complete programmes from material that would not otherwise be available and also as a source of material from which extracts may be used, for example, for illustrating talks or for inclusion in other composite programmes. In the future there is also likely to be an increasing use of fine-groove disks recorded by the BBC and these, generally speaking, will be used in the same ways. In all applications a smooth presentation of programme can be obtained only if it is possible to commence reproduction on the right word or note and to do so at exactly the right moment. In some cases as, for example, when using recordings to illustrate a talk, a considerable number of excerpts may be required in quick succession, and to enable this to be done with the minimum number of machines and operators the process of 'setting up' must be as easy and as quick as possible.

One method of doing this that has long been used with coarse-groove 78 r.p.m. records is to have the pick-up arm fixed to a carriage which runs on a rail arranged in such a way that the pick-up head moves radially across the disk. A raise/lower mechanism is also provided together with a scale and a vernier control for fine adjustment of the pick-up position when it is raised off the disk. By these means the pick-up can be set quite precisely at any desired position over the rotating disk and can be lowered on to it at the instant required. Since the groove is of spiral form, however, a stylus that has been positioned so as to drop precisely into the groove at one position of the disk would descend on the 'land' between two grooves* if it were lowered when the disk had rotated half a turn and there would then be the possibility that it might slide off into the groove on either side. There is thus a fundamental uncertainty of one groove in the selection of a point on the disk by this procedure unless the pick-up is always lowered when the disk is in the same rotational position.

In practice the uncertainty can be greater than this because the disk usually rotates slightly eccentrically. This is because the hole is seldom precisely in the centre of the spiral groove on a processed disk (the tolerance allowed by the British Standard† is 0·005 in.) and there may be additional eccentricity caused by the necessarily imperfect fit of the disk hole on the turntable centre pin. In practice, therefore, a really accurate selection of a starting point can only be obtained by lowering the pick-up with the disk in a predetermined rotational position and with 78 r.p.m. records this is done with sufficient accuracy by observing the rotational position of the record label when operating the lowering mechanism. Such a procedure is not practicable on 33⅓ r.p.m. records, however, for whether the lowering of the pick-up is 'keyed' to the rotational position of the disk by the eye of the operator or by electrical or mechanical interlocks, it still remains that, if the required point in the recording has just passed from under the pick-up stylus at the moment it is required, then nearly two seconds must elapse before it is once again under the pick-up. This uncertainty of timing is prohibitive.

With another arrangement that has been used for coarse-groove records the same carriage and scale are used for the approximate location of a point in the recording. Precise positioning, however, is obtained by resting the pick-up with its stylus at a predetermined position on the record while the latter is held stationary a short distance above the rotating turntable. By dropping the record on to the turntable at the appropriate moment it can be brought up to speed very rapidly and transmission during the short time that the disk is accelerating can be avoided by a slightly delayed operation of the fader.

This is substantially the procedure that has been adopted for selecting the starting point on fine-groove records though, in fact, the quick start of the disk has been obtained by raising the turntable up to the disk and not by dropping the disk on to the turntable. An optically projected scale has been added to give the maximum useful accuracy of positioning and the pick-up that is employed has a type of stylus mounting that permits the disk to be turned safely either forwards or backwards with the pick-up resting on it. The precise position of a point in the recording can therefore be found in just the same way as is done with magnetic tape, that is by listening to the output from the reproducing head while moving the record to and fro by hand.

3. Turntable

Although the need for using two or more turntables in sequence to ensure continuous reproduction is clearly less with long-playing fine-groove records than it has been with coarse-groove 78 r.p.m. disks, nevertheless, the need for transferring reproduction rapidly from one turntable to another does sometimes arise. It is important in such cases that the turntable speeds shall be sufficiently alike for no pitch change to be apparent and this implies a much greater precision than is required to meet the normal transcription turntable speed tolerance of $\pm 0 \cdot 5$ per cent (British Standard 1928 : 1955).

Absolute accuracy in the mean speed of a number of turntables can, of course, be achieved by driving each of them either directly or through gears from a synchronous motor, but while such arrangements are perfectly practicable they tend to be rather expensive if a high standard of performance in all other respects is to be obtained. Turntable units which involve friction drive between the motor

* Although there is only one spiral groove on each side of a gramophone record it is usual to refer to each turn of the spiral as a groove and thus to speak of adjacent grooves (for adjacent turns) and grooves per inch (instead of turns per inch). This conventional terminology is used here.

† British Standard 1928 : 1955. Gramophone Records, Transcription Disk Recordings, and Disk Reproducing Equipment.

and the turntable are generally appreciably simpler and cheaper but they cannot readily be manufactured to have an accurate uniformity of speed between one turntable and another. One way of avoiding this difficulty is to use a friction drive design together with a speed adjustment since, in conjunction with a stroboscope, this will enable any turntable to be set quite precisely to its nominal speed without involving any prohibitive accuracies in manufacture. The usefulness of this arrangement naturally depends on the speed stability of the turntable for it is important that, once set, the speed should remain substantially constant and should not drift because of temperature changes or vary with the position of the pick-up on the disk or with normal variations of mains voltage.

A small amount of speed adjustment is not only useful as a cheap means of providing exact speed adjustment when it is required; it can sometimes be convenient in other ways. For example, it is occasionally desired to reproduce a recording of music in exact pitch with a musical instrument that is in the studio and in such a case it may be necessary to run the record at a speed different from the nominal. Again there are cases, particularly with old recordings and with those made on mobile equipment, where the recording turntable speed was not accurate and it may be useful to compensate for this by a corresponding adjustment of the replay speed.

For these reasons use has been made of a commercial transcription turntable unit which has a continuous range of speed variation of $\pm 2\frac{1}{2}$ per cent provided by means of an adjustable eddy current brake. The fact that the speed can be changed by means of a brake of modest size naturally implies that the available torque is not very high and this in turn implies not very rapid acceleration from rest. However, the torque is sufficient for normal reproduction and as considerable modifications are in any case necessary to provide the quick starting facilities steps have been taken to increase the torque during starting. The available speed variation of $2\frac{1}{2}$ per cent changes the reproduced pitch by about half a semi-tone and this is sufficient for most purposes. On the very rare occasions when a larger speed variation is required the turntable can be operated from a power supply of variable frequency.

Aside from these considerations, which, to a large extent, are peculiar to service in a broadcasting organization, it is naturally essential that a disk replay turntable should have all the features that are necessary to give it a good general performance in any other application. It should, in fact, run true, should have a low level of vibration and rumble, and it should rotate with sufficient uniformity to be free from trouble with the cyclic pitch changes that are normally referred to as wow and from the high frequency fluctuations that are referred to as flutter.*

4. Pick-up

Perhaps the most important requirement for a disk reproducing pick-up is that it should have the lowest possible mechanical impedance at the stylus tip. This not only implies that the smallest possible pressures are imposed on the groove walls in moving the stylus from side to side but also that the downward loading of the pick-up on the disk, that is to say the playing weight, can be correspondingly small. The wear on the disk is then minimized and the distortions that arise from the elastic and non-elastic deformations of the groove under the stylus tip are kept as small as possible. It is also essential that the stylus should be of suitable size and shape and that reproduction should be substantially free from distortion introduced by the pick-up itself.

Aside from these general requirements, which naturally apply in any application, there is considerable disparity between the relative importance of other pick-up features in broadcasting or in domestic applications. Thus, for example, an output level that is high enough to drive an output pentode directly is often an important requirement for a pick-up that is to be incorporated in moderately priced domestic equipment, whereas in a broadcasting service the output level of the pick-up is of little importance provided that it is high enough to ensure a good signal/noise ratio at the grid of the first amplifying valve. Beyond this, increased output level from the pick-up is of little value, for additional amplification is both cheap and easy to obtain.

Again, when a pick-up is intended for use with a variety of different types of domestic equipment it is desirable for it to give an appropriate frequency response with only a simple form of electrical termination. In a broadcasting service, on the other hand, the output of the pick-up must in any case be amplified up to normal line level and there is little difficulty in providing almost any equalization that may be necessary to change the response of the pick-up to the one desired. All that is required, therefore, is that the pick-up response curve shall be free from the violent peaks and inflections that indicate the presence of resonance effects.

In these two ways the demands of a broadcasting service are less exacting than those of domestic use but there are other respects in which the position is reversed. This is notably the case as regards the uniformity of performance of different specimens and the stability of performance of each individual pick-up over long periods of use and with changes of temperature. The need for such uniformity is indicated by the fact already mentioned that it will sometimes be necessary to transfer reproduction rapidly from one turntable (and one pick-up) to another while replaying the same recording and it must be possible to do this without any apparent change in reproduced quality. The requirements are, of course, much more stringent still in those cases where repeated re-recording may occur, for an error of a few decibels in the response curve may be acceptable enough on a direct reproduction but be quite intolerable when it is multiplied several times by a re-recording process.

There is another property of a pick-up which is usually not of much significance but which becomes very important indeed with the editing procedures already outlined.

* British Standard 1980 : 1953.

This arises because, if a specific point in a recording is to be found at all quickly, it is necessary to turn the disk both forwards and backwards and it is therefore of the first importance that reversed rotation shall not cause the pick-up stylus to dig into the disk surface. Broadly speaking, this implies that the stylus must be so mounted that the frictional forces applied to it by the disk do not materially increase its downward pressure and one way in which this may be achieved is by mounting the stylus on the end of a cantilever spring which lies more or less horizontal and close to the disk surface.

Such a construction has an additional advantage in that the stylus mounting may be made to protrude beyond the head casing so that it is readily visible at all times. This may not appear to be a matter of much importance for, in principle, the editing operations described above can be carried out without seeing the stylus at all. In practice, however, it is found that the operator gains usefully in confidence and ease if the stylus is not out of sight underneath the head.

At the time when this development was carried out there was not, so far as is known, any pick-up commercially available in this country which wholly met all the needs of this particular application. There was one head, however, which was very satisfactory from the editing point of view since the stylus was mounted on a cantilever spring so that it was both easy to see and easy to replace if worn or damaged. This head had a sufficiently low mechanical impedance and was of modest price but it was a crystal unit of the Rochelle salt type. Now although this type of pick-up has been very successful in domestic use, it has a number of inherent characteristics which make it much less suitable for use in broadcasting and similar applications. For example, the Rochelle salt crystal itself is very hygroscopic and must therefore be very thoroughly sealed if it is to be protected from attack by moisture in the atmosphere. Moreover, it is rather fragile and unless well protected from shock by a suitable mounting and driving mechanism it can easily be fractured by mechanical abuse. The crystal is inherently sensitive to changes of temperature and it may only be used below about 110°F; above this critical temperature irreversible changes occur which render the crystal permanently useless. The response curves obtained with Rochelle salt heads are usually less smooth than those obtainable from some other types of pick-up and, for the most part, such heads are not very uniform as between one specimen and another or over long periods of use. For all these reasons this type of head is generally considered to be unsuitable for applications of the broadcasting type where a high degree of consistency of performance is required and it was necessary to investigate the consistency and stability of these particular pick-up heads in service conditions before considering their use in the BBC.

Investigations of reliability and stability are necessarily protracted but the results of a large number of tests may broadly be summarized as follows. As regards general robustness and the ability to withstand considerable mechanical abuse these crystal heads proved very satisfactory, probably because of the protection to the crystal element that is afforded by the stylus mounting which consists of a compliant cantilever lying between guard blades arranged to limit the possible deflection and therefore the force that can be transmitted to the element. A reasonable consistency of performance of any one sample over satisfactory periods was generally obtained and although the temperature effects were greater than desired they could be minimized by a suitable choice of terminating impedance. The critical temperature at about 110°F was of no importance for normal studio operation though it does limit the usefulness of this type of head for mobile work and in tropical countries.

The principal weakness in the performance of these pick-ups from the point of view of a broadcasting organization lay in the variations of response between different samples which, though acceptable in domestic use, are large enough altogether to preclude their use for very critical applications such as multiple re-recording where an error in a pick-up response curve may be multiplied several times. Nevertheless, it has been found possible by means of a reasonable selection procedure to keep the response curves of a large number of heads within limits which are quite acceptable for the straightforward reproduction of gramophone records. These heads, therefore, give an adequate standard of performance together with unusual robustness and suitability for the editing procedures involved.

5. Amplifiers

It goes without saying that the electronic portion of new reproducing equipment is based on the use of standard BBC amplifiers.(1) Since these have been designed primarily for other uses they do not necessarily provide the most economical use of components in this particular application, but the comparatively modest number of fine-groove reproducers that are likely to be required does not make it economically justifiable to design amplifiers specially for them.

It is always necessary in broadcasting practice to provide 'pre-fade listen' facilities on reproducing equipment; that is to say to arrange that reproduction from any pick-up can be listened to on headphones even though the corresponding fader is turned down and there is no output from the desk. This feature is essential to enable the preparation or 'setting up' procedures to be carried out on one desk of a bank while reproduction to transmission is taking place from another. It is also necessary for the operator to be able to listen on headphones to a programme originating from outside the desk since this may indicate, for example, the end of the preceding programme. It is therefore convenient to arrange for a single key to switch the headphones either to 'pre-fade listen' or to a selected line taken from the 'ring main', a circuit which feeds a variety of programmes to each studio and reproducing room.

6. General Arrangement of a Fine-Groove Replay Desk

There are, of course, a large number of detailed requirements for a new reproducing desk ranging from the rather obvious one that it should not require more space than existing similar equipment to the provision of special means for linking the outputs from various numbers of desks, and arranging for the combination to give outputs of the appropriate levels into the various impedances that are involved in different applications. Most of these points will be touched on in the following description of a new fine-groove reproducing desk that has been developed for BBC use.

There was one major question, however, that had to be decided before the design of a fine-groove reproducing desk could proceed, namely whether such a desk should include facilities for replaying coarse-groove records as well. This involved implications as to the turntable speeds and the turntable diameter that might be required.

There are advantages and, of course, disadvantages in building desks that can play both coarse- and fine-groove records. The advantages of the universal type of equipment in giving the maximum range of facilities in the minimum of room space are obvious enough but, on the other hand, the risk of replaying one kind of disk with the stylus suitable for the other is considerably increased. The effect of such an error, unlike that of playing a disk at the wrong speed, may not be at all immediately recognizable and although in the case of a fine-groove stylus being used on a coarse-groove disk the effect may be no worse than an increase of distortion, the use of a coarse-groove stylus on a fine-groove disk is likely to lead also to the operational disaster of the stylus leaving the groove altogether and sliding across the disk. It is possible to provide some measure of protection against such errors but nothing is so effective in this respect as the use of different types of equipment for replaying the two types of record.

A further consideration is that the use of fine-groove records in this country has so far followed rather closely on the practice in the U.S.A. but with a few years' delay. The 78 r.p.m. gramophone record has now virtually ceased to exist in the U.S.A. and it is possible that in the course of a few years it will disappear here too. If that occurs, the provision of coarse-groove facilities on gramophone record replay equipment will then become an unnecessary and, indeed, a wasteful complication. The existence of large numbers of coarse-groove records of historical interest naturally means that some coarse-groove replay equipment will be required for a very long time to come, but that is rather a different matter from needing to provide such facilities on all replay equipment.

None of these considerations is entirely decisive. What was decisive at the time when the new replay desk was designed, however, was that the editing facilities that could be provided on it, though entirely acceptable for the purpose, were not considered, from the operational point of view, to be a complete substitute for those hitherto in wide use on existing coarse-groove desks. These latter facilities could not be adapted for fine-groove work and no other course was possible, therefore, but to build desks exclusively for use with fine-groove records. This position, however, may not be permanent and it may be necessary in the future to re-consider whether the advantages of such a procedure do or do not on the whole outweigh the disadvantages.

The decision to build a desk specifically for fine-groove records went a long way to deciding the question of what turntable size and speeds would be required. The coarse-groove 16 in. diameter disk is in any case likely to be entirely superseded by magnetic tape and for practical reasons it seems unlikely that fine-groove recording will ever be used in any substantial measure on disks larger than 12 in. diameter. A 12 in. diameter turntable can therefore be adopted with reasonable confidence.

With regard to turntable speed, fine-groove recording is normally carried out at either 33⅓ or 45 r.p.m. There have been no major commercial issues of fine-groove 78 r.p.m. records though a few special recordings have been made at this speed and some peculiar records, made with a coarse-groove cutter but with less depth and a closer pitch than usual, have been issued in Germany and Holland. It is difficult to be entirely certain of the trend of future development in a situation which is as fluid as this, but it was judged that any major development of 78 r.p.m. fine-groove records was unlikely. If this is true, it follows that a 78 r.p.m. turntable speed on a 'fine-groove' desk would be undesirable since its presence would not serve any useful purpose and its absence would ensure that coarse-groove disks could not be played accidentally with a fine-groove stylus.

The design of the desk therefore provided for fine-groove disks only with speeds of 33⅓ and 45 r.p.m. and with a 12 in. diameter turntable.

PART II DESCRIPTION OF THE FINE-GROOVE REPRODUCING DESK DRD/5

7. General

Fig. 1 shows a general view of a single turntable reproducing desk that has been developed along these lines. It consists essentially of a wooden carcase which contains two main assemblies, one consisting of the turntable itself, together with the pick-up and various controls, the other comprising the amplifiers, equalizers, and other electrical parts. This latter unit is in the form of a tray to which the control panel is permanently attached and which slides into position in the desk like a drawer. The general arrangement of the tray unit is shown in Fig. 2, while Fig. 3 shows it in the desk carcase but half withdrawn. Fig. 3 also shows

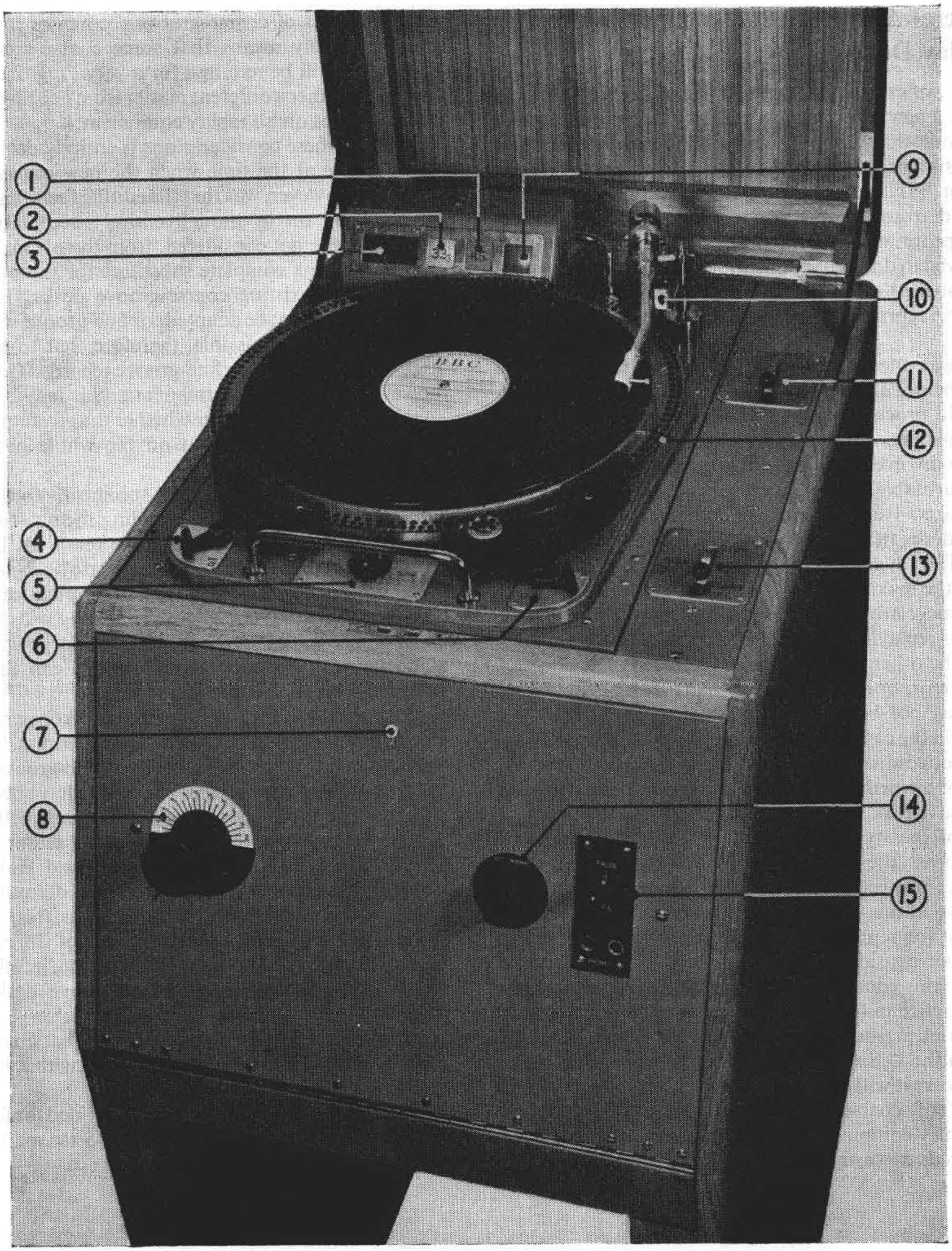

Fig. 1 — Fine-groove Reproducing Desk DRD/5

1. *Motor-speed Indicator*
2. *Motor-speed Indicator*
3. *Pick-up Scale*
4. *Motor On/Off Lever*
5. *Fine Control, T.T. Speed*
6. *Speed-Change Lever*
7. *Mains Indicator Lamp*
8. *Programme Fader*
9. *Fader Indicator Lamp*
10. *Pick-up Lifting Member*
11. *Pick-up Raise/Lower Lever*
12. *Perspex Disk*
13. *Disk Start/Stop Lever*
14. *Top-cut Switch*
15. *Pre-fade Listen Key*

the turntable unit raised from the desk as it would be for maintenance.

8. Turntable Unit

It will be seen from Fig. 3 that the turntable unit itself consists of two parts, a main unit on the left-hand side which carries the turntable and pick-up and, on the right, a narrow panel which carries the two control levers for lowering the pick-up and for starting the record. In the working condition, this narrow panel carrying the controls is attached firmly to the desk but the main unit on the left which carries the turntable and pick-up, rests on four conical springs two of which can be seen in Fig. 3 surrounding the rods which act as supporting legs. These springs provide a substantial measure of mechanical isolation of the turntable unit from external shock, a feature which is of the utmost importance in this application because, with a pick-up stylus resting only lightly in a shallow groove, quite a modest shock may cause it to jump entirely out of the groove. In service conditions it is, of course, impossible altogether to avoid occasional accidental knocks on the desk or vibration and the effects of impact on the floor.

When the turntable unit is in the raised position, the four legs on which the conical springs are mounted engage in suitable recesses in the desk and support the unit safely in the position shown in Fig. 3. When the turntable unit is lowered into the working position the legs hang down freely inside the desk. They are accessible when the front panel is open, however, and when rotated they serve to adjust the level of the turntable unit on its supporting springs.

The arrangement adopted for providing quick starting* of the record is shown diagrammatically in Fig. 4. The record (1) rests on a perspex disk (2 in Fig. 4, 12 in Fig. 1) which is of larger diameter than the turntable and can rest on the stationary pads (3). The turntable (4) has a footstep bearing (5) which rests on an eccentric cam (6), the weight of the turntable being partially counter-balanced by a spring which is not shown in the diagram. When the turntable is in the lowest position it can rotate freely with its top surface out of contact with the perspex disk though its centre pin passes through both the disk and the centre hole of the record. The turntable is normally left rotating in this position while the pick-up is being set to the required point on the record. Then, when the footstep cam is rotated by the mechanism shown, the turntable is raised slightly so as to bring it into contact with the perspex disk and to lift it from the supporting pads (3). As the rotating turntable is heavy and the perspex disk and the record are light, the latter are brought up to the turntable speed quite quickly.

Early tests showed, however, that the record was not accelerated quite quickly enough in this way, for although the inertia of the record and the perspex disk together was much less than that of the turntable, nevertheless, it was large enough to slow the turntable down appreciably during the starting operation. In principle there were three ways in which this difficulty could have been overcome; the inertia of the record and the perspex disk could have been reduced, the inertia of the turntable could have been increased, or arrangements could have been made to increase the useful torque of the driving motor. It was not possible to reduce the inertia of the record and the perspex disk in any very marked degree and substantial increase in the inertia of the turntable would have involved fairly extensive redesign of the commercial turntable unit that it was desired to adopt. On the other hand the use of a larger motor to increase the useful turntable torque would have made the turntable speed more independent of load and so would have introduced difficulties in other directions, since a larger brake would have been required to obtain the same range of speed adjustment. The expedient adopted therefore was to increase the motor torque temporarily during the starting operation by applying a higher voltage and the way in which this has been done is shown in Fig. 5.

It will be seen that, when the turntable is at rest (but with a mains supply connected to the desk) the capacitance C1 receives a charge from a metal rectifier. The operation of raising the turntable into contact with the perspex disk also operates the switch S1 and the capacitance C1 then discharges through the winding of the relay K1. The lower contacts of this relay therefore open and insert a capacitance C2 and resistance R2 in series with the turntable driving motor. The value of C2 has been chosen to give an approximation to series resonance with the inductance of the motor windings, and the terminal voltage of the motor is therefore increased. The resistance R2 is provided to limit the current when, after C1 has discharged, the relay K1 releases and its lower contacts close again. The time during which the relay is operated and a high voltage is applied to the motor may be adjusted, by variation of the resistance R1, to be just that required for the turntable to reach full speed.

Associated with this arrangement for increasing the motor torque during the starting period there is a second relay K2 which keeps the pick-up automatically 'muted' except when the record is running at full speed. To ensure this, the switch contacts, S1 and S2, are mechanically coupled to the control lever (7 in Fig. 4, 13 in Fig. 1) in such a way that S1 operates as soon as the lever is moved away from the 'stop' position and S2 operates when it reaches the 'start' position. With the lever in the 'stop' position and the record stationary the conditions are as shown in Fig. 5 and the relay K2 is energized via S2 thus ensuring that an accidental noise from the pick-up cannot go out to transmission even if the fader has been inadvertently left in the 'up' position. As soon as the control lever is moved away from the 'stop' position, the relay K1 operates and applies an overvoltage to the motor for a time pre-set by the adjustment of R1. The relay K1 then releases and the supply to the relay K2 via its upper contacts is removed. If the control lever has been moved fully into the 'start' position, the contacts S2 are open and the relay K2 therefore releases, thus disconnecting the pick-up

* See also Viljoen J.P.T., South African Broadcasting Corporation, British Patent Specification No. 702090.

'mute' circuit. However, if the control lever has not reached the 'start' position by the time the relay K1 releases, the relay K2 continues to be energized via the contacts S2 and, consequently, no matter how slowly the control lever is moved the pick-up output is not available until the turntable has been fully raised to the operating position. Similarly, since S2 closes immediately the control lever is moved away from the 'start' position the pick-up is 'muted' as soon as the turntable speed begins to decrease. Thus, whether the control lever is operated quickly or slowly, the output from the pick-up cannot go to transmission except when the turntable is up to speed.

The 'muting' of the pick-up is carried out not by open circuiting or short circuiting but by inserting the attenuator R5, R6, R7 since by this means the proper impedance relationships are maintained and the risk of static charges producing clicks is removed. When the relay K2 releases so as to remove the 'muting', the shunt resistances R5 and R7 are disconnected and the series resistance R6 is short circuited by the two relay contacts in parallel. The position of the 'muting' switch in the circuit is shown in the block schematic of Fig. 8 from which it will be seen that the feed for the 'pre-fade listen' amplifier comes before the 'muting' switch which therefore controls only the programme output from the desk leaving the 'pre-fade listen' facility available for 'setting up'.

Fig. 5 also shows the circuit R3, R4, C3 which is arranged to apply a 'peaky' waveform to the neon stroboscope lamp so as to obtain a more sharply defined stroboscope pattern than is possible with mains voltage applied directly to the lamp. The stroboscope pattern is provided by two rings of black spots, one for 45 r.p.m., and one for $33\frac{1}{3}$ r.p.m. which, as can be seen in Fig. 1, are carried on the outer edge of the perspex disk. The neon lamp is mounted

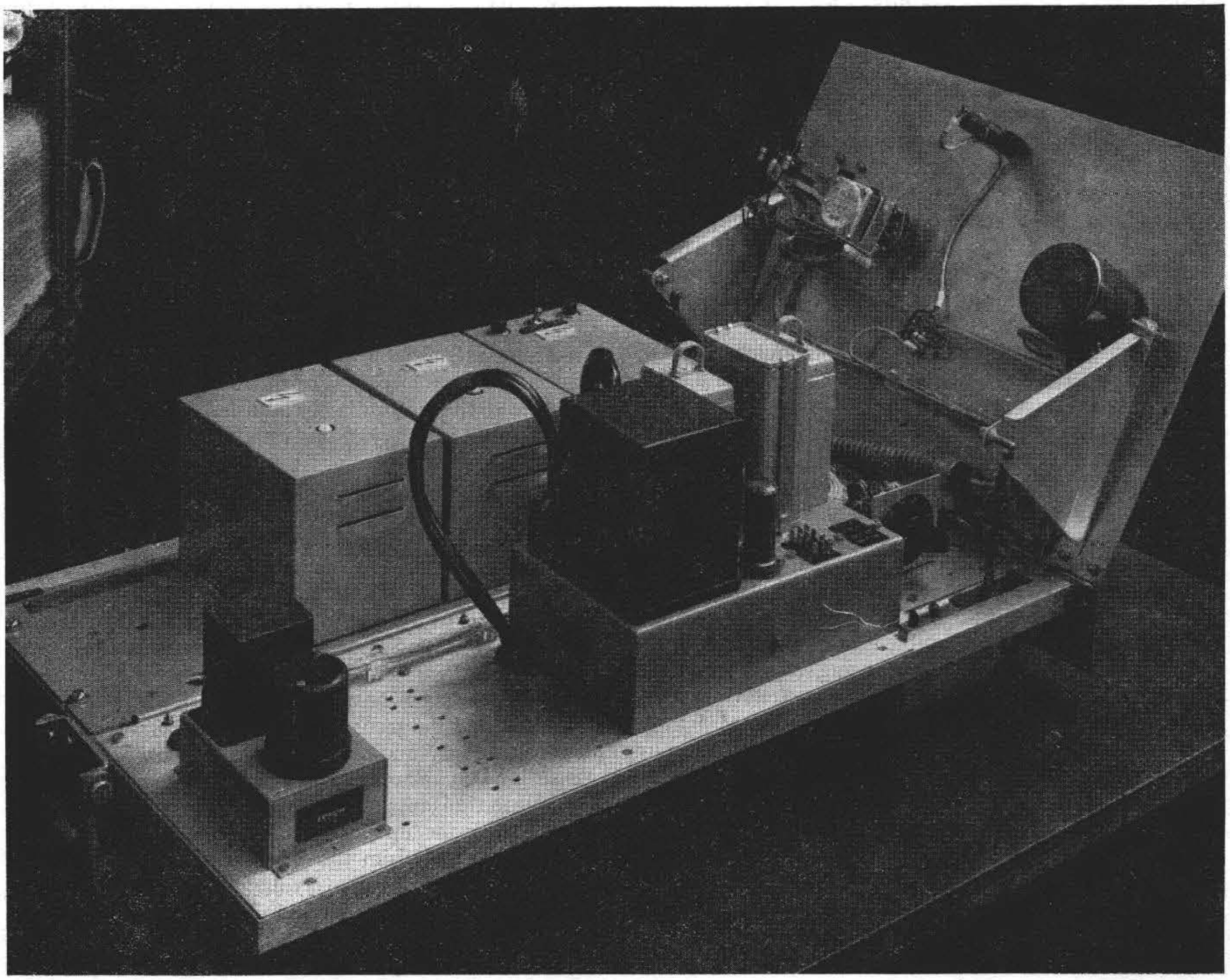

Fig. 2 — General arrangement of the Tray Unit

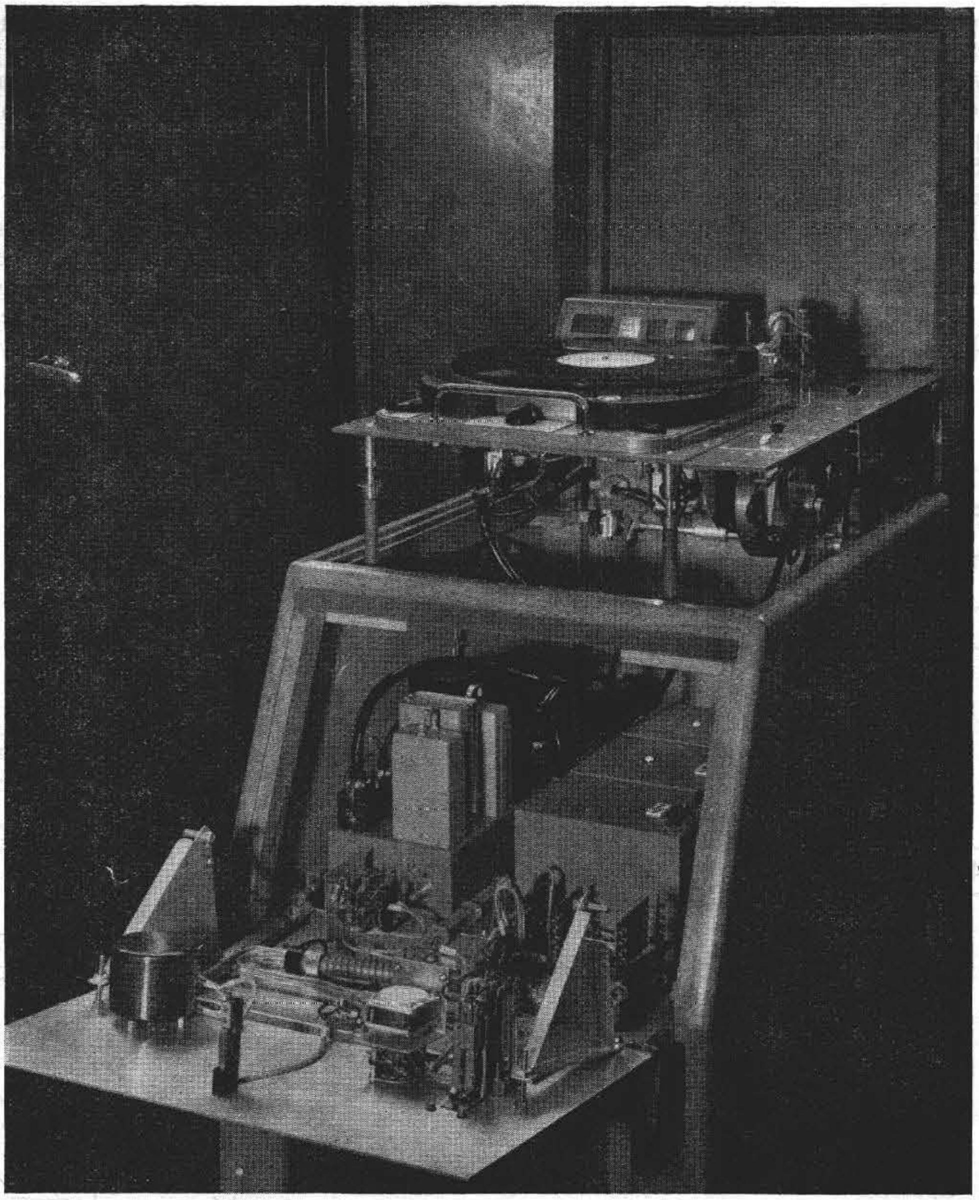

Fig. 3 — The Turntable and Tray Units withdrawn for maintenance

in a recess in the right-hand pad on which the perspex disk rests when stationary and it is so positioned as to be directly beneath the two rings of stroboscope markings. By looking directly downwards on to the neon lamp through the perspex disk the stroboscope pattern is readily seen and the turntable speed can be adjusted to give a stationary pattern by means of the fine control shown at 5 in Fig. 1.

9. Turntable Drive

The turntable itself is driven by an induction motor and in its normal state any one of the three speeds, 78, 45, and 33⅓ r.p.m., can be obtained by engaging an intermediate rubber wheel between the appropriate diameter of the stepped motor shaft and the internal surface of the turntable rim. In this case only 33⅓ and 45 r.p.m. are required and a stop has therefore been inserted to eliminate the third position. The control for setting the intermediate wheel to the appropriate position along the stepped motor shaft is interlocked with the turntable starting switch in such a way that it can be moved only when the switch is in the 'off' position. When the switch is in the 'off' position the intermediate wheel is automatically removed from contact with the motor shaft and it can therefore be moved from step to step without fear of damage.

Unlike a normal reproducing turntable which, if rotating, can readily be seen to do so, this turntable is difficult to see when it is in the lowered position with the perspex disk and record stationary above it and a clear indication is required of whether it is running and, if so, at what speed. Switches have therefore been coupled to the speed change lever (6 in Fig. 1) and the motor On/Off lever (4 in Fig. 1) so that, when the turntable is running one or other of the central windows (1 and 2 in Fig. 1) in a lamp housing at the rear of the desk illuminates to show the speed selected. When the motor On/Off lever (4) is in the 'Off' position neither of the windows is illuminated.

avoided by fitting a 'snap over' spring so that if the operating lever were released in an intermediate position it would immediately spring to one end of its travel or the other but, if the spring were sufficiently strong to ensure that the mechanism could never stick part way, then the lever, if released in the middle position, would hit the end of its travel with a considerable shock. The use of mechanical friction or of dashpots or similar devices to avoid this is unsatisfactory but the difficulties have been overcome by fitting a 'snap over' spring and controlling the free running speed of the mechanism by means of a heavy flywheel.*

* Brit. pat. application No. 29894/55.

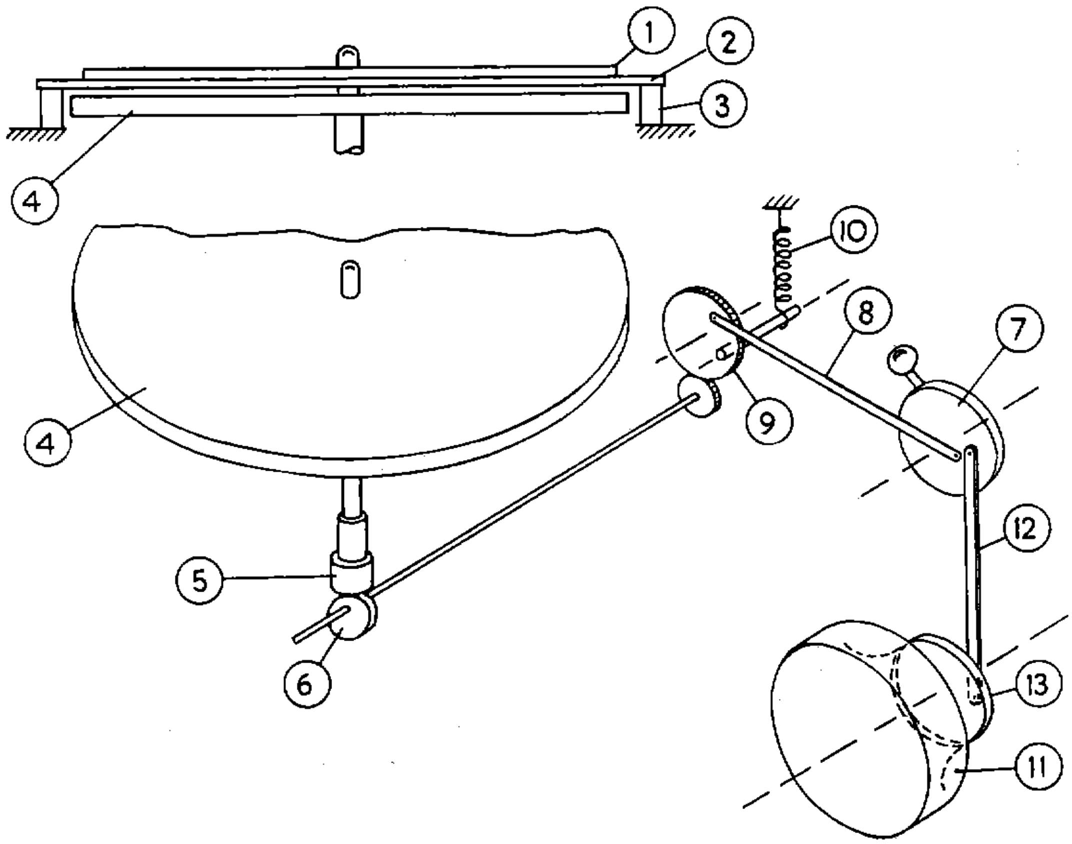

Fig. 4 — Diagram illustrating quick-starting arrangements

The arrangement of the mechanism that is used for operating the eccentric cam which raises and lowers the turntable is shown diagrammatically in Fig. 4. The simplest possible arrangement that could be used for this purpose would be to connect the operating lever (7 in Fig. 4, 13 in Fig. 1) directly or through gears to the cam but this would have the disadvantage that if the lever were not moved fully into the 'stop' or 'start' position but were left in an intermediate position the turntable would also remain in an intermediate position and faulty operation would probably result. The risk of this happening could be

The general arrangement is shown diagrammatically in Fig. 4 which indicates that the operating lever (7) is connected to the eccentric cam (6) via a link (8) and gears (9), one of which carries the actuating spring (10). The linkage is arranged so that the spring provides a 'snap over' action centred near to the 'stop' position of the operating lever (7) which therefore locks into the 'stop' position but, if slightly displaced from it, becomes spring loaded in the direction of the 'start' position.

The operating lever (7) is also coupled to a flywheel (11) by means of a link (12) and a friction clutch (13) and the

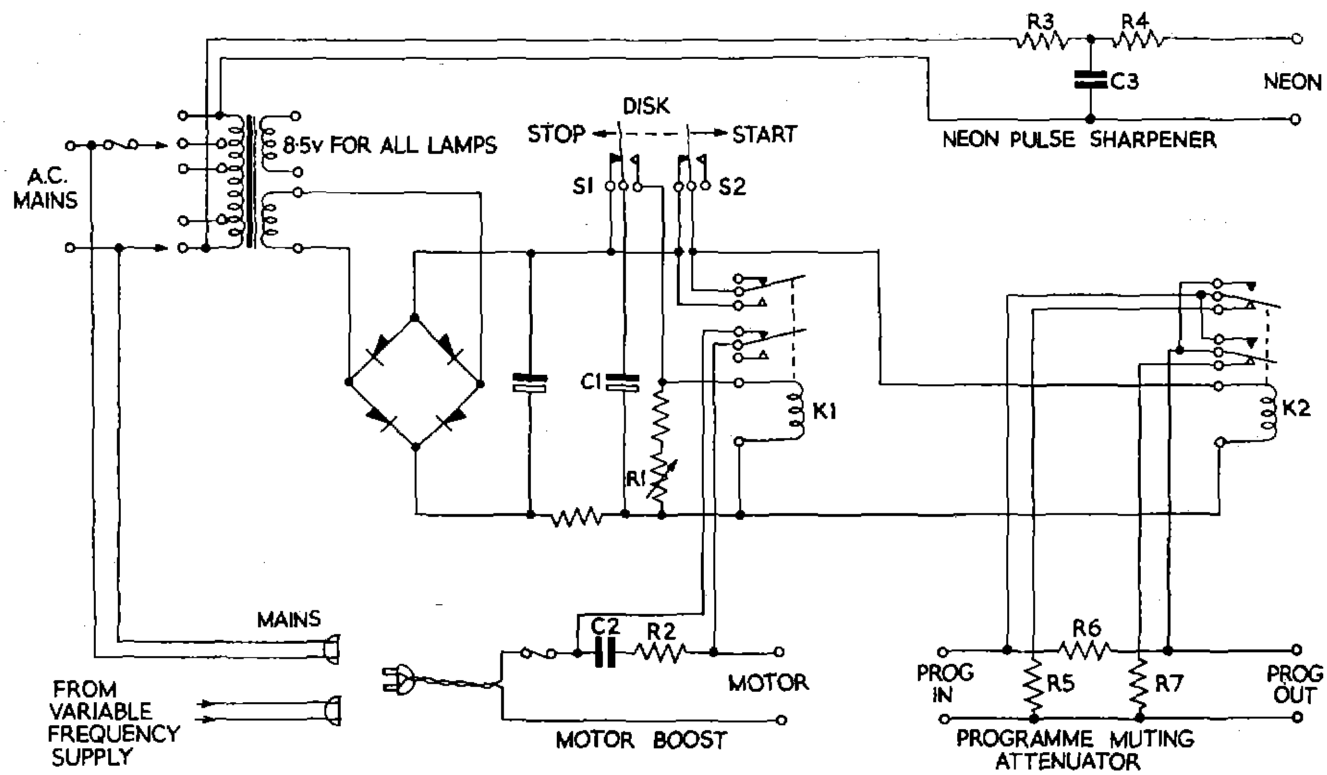

Fig. 5 — Diagram of circuit arrangements of control system

linkages are arranged so that the velocity ratio between the flywheel and the cam increases as the mechanism moves from the 'stop' to the 'start' position, that is to say, the flywheel accelerates with respect to the cam. In this way the flywheel exerts a reactive torque and if the lever (7) is slightly displaced from the 'stop' position and then released the mechanism causes the cam (6) to rotate with nearly constant velocity. Since the flywheel is coupled to the rest of the mechanism by a spring loaded friction clutch (13) the energy stored in it at the end of the operation is dissipated in the coupling silently and without shock. Moreover, although the operating lever, once displaced from its 'stop' position, will continue to move smoothly and at a predetermined speed into the 'start' position, the control imposed by the flywheel can be overridden and, if more rapid operation is required, the lever can be moved as quickly as desired in either direction.

The underside view of the turntable unit in Fig. 6 shows how this mechanism for operating the lifting cam is arranged.

10. The Pick-up and its Mounting

As already stated the pick-up head is a commercial crystal unit of the Rochelle salt type but a special arm has been provided so as to operate an optical system which gives an accurate indication of the pick-up position.

The arm is made of a hard aluminium alloy tube and it carries on the forward end a plastic moulding on to which the head clips. This tubular arm pivots in miniature ball races about a horizontal axis in a trunnion member which is itself attached to a hollow vertical shaft running in ball journal bearings housed in the mounting base. The vertical shaft has an extension projecting downwards below the mounting plate and on this extension is the graticule of the optical system mentioned below. The trunnion member and the mounting base are made of aluminium alloy whilst a brass counterweight on the rear end of the arm enables the playing weight to be adjusted.

The pick-up can be raised and lowered by means of a sector of about 2 in. radius (10 in Fig. 1) that is positioned under the pick-up arm concentric with its vertical axis. This sector is moved up or down by a simple rack and a pinion which is connected by a shaft and flexible couplings to the operating lever (11 in Fig. 1). This lever is spring loaded in the lower direction but it locks when in the raised position.

11. Pick-up Position Indicator

Although the precise positioning of the pick-up on the disk is done by listening to its output when the disk is moved, nevertheless some form of scale or indicator giving the approximate position of the pick-up is required if only to enable the pick-up to be set again to the same position as quickly as possible on another occasion. The use of a pointer attached to the pick-up arm and moving over or near to an arc-shaped scale is hardly a practicable way of meeting this need for, even if the pointer were as long as the pick-up arm, one minute of playing time would cover only about $\frac{1}{8}$ in. of scale length. A substantial magnification is therefore required. Other forms of indicator, coupled mechanically or electrically to the pick-up arm, are generally undesirable not so much because of any difficulty of ensuring adequate accuracy at the required magnification but because it is virtually impossible to use them without imposing some restraint on the movement of the pick-up arm. With lightweight pick-ups operating at a playing weight of a few grammes it is, of course, of the utmost importance that the arm shall move as freely as possible.

The optical type of indicator, however, permits large magnifications to be obtained in a simple and straightforward manner and without in any way impeding the movement of the pick-up arm. This form of indicator was therefore adopted. The lower limit of magnification was set by the considerations outlined above as being about x2 or x3 while the upper limit was set by the normal record eccentricities. As already noted, the existing British Standard permits an eccentricity of 0·005 in. between the centre hole of the record and the groove spiral. This, of course, implies a 'swing' of 0·010 in. or $2\frac{1}{2}$ 'grooves' on a 250 grooves/inch record and with a disk having this

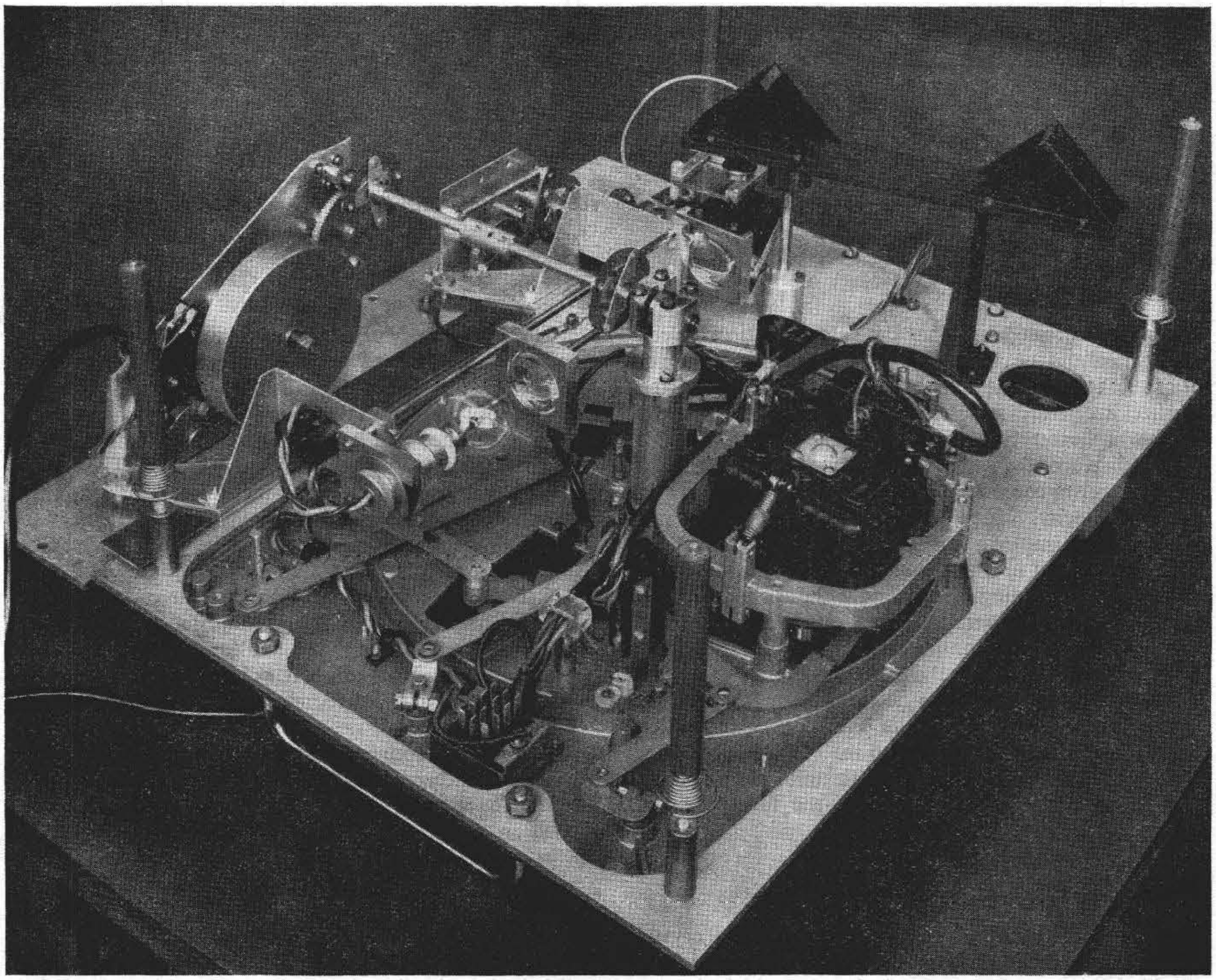

Fig. 6 — Underside of the Turntable Unit showing lifting cam operating mechanism and pick-up position indicator

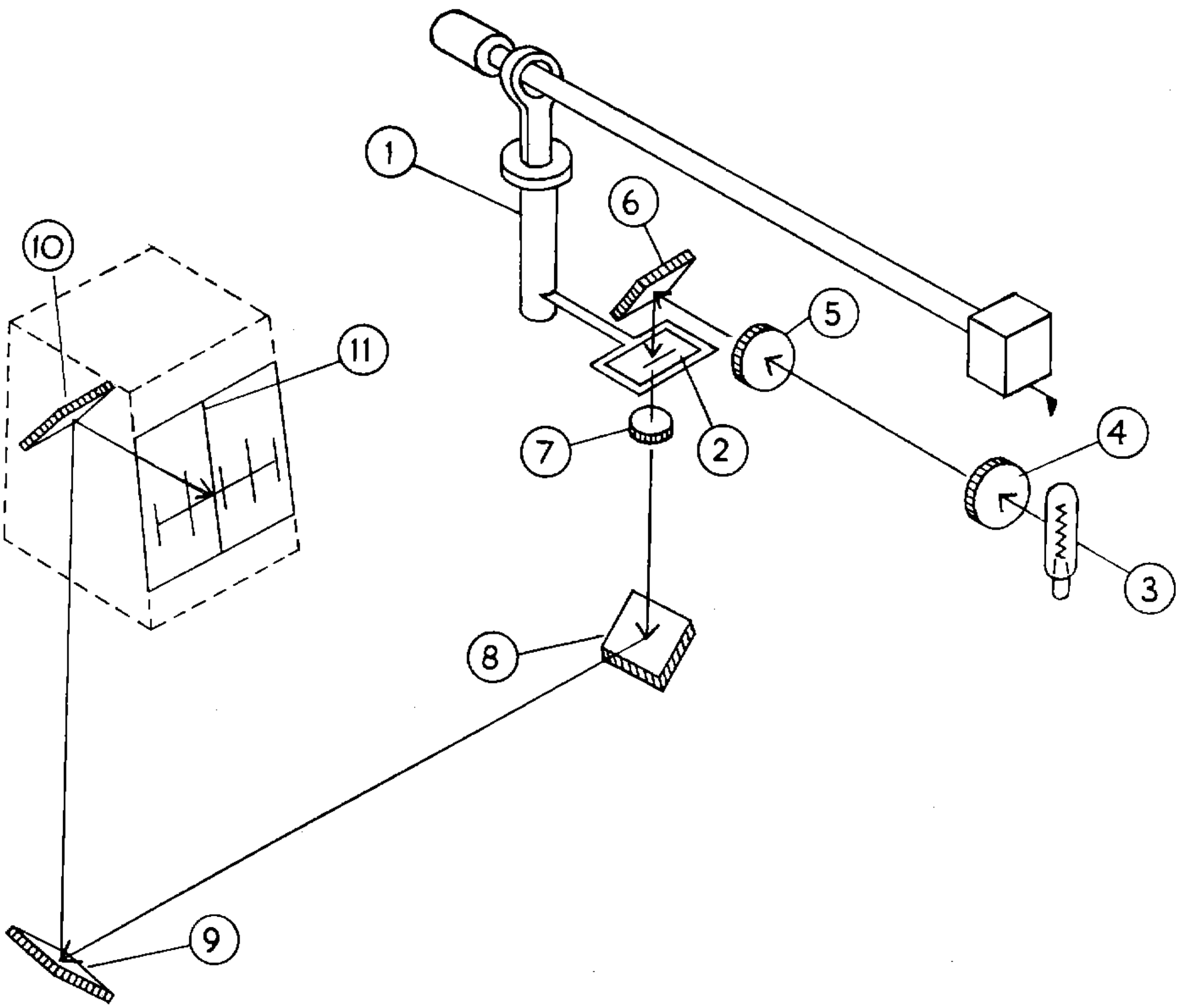

Fig. 7 — Diagram of optical system

eccentricity the scale reading must therefore vary or 'swing' over a range of $2\frac{1}{2}$ grooves during each revolution. This movement makes a very great magnification not only useless but positively inconvenient and, as a compromise, a magnification of about x6 was chosen. There are no precise standards for groove pitch on fine-groove records and, indeed, in some cases the groove pitch is varied throughout a single recording in accordance with the recorded amplitudes. A scale cannot therefore be made to give any indication of the number of grooves or the playing time and the precise magnification and the method of scaling are unimportant provided that they are the same on all turntables.

There are two basic types of optical system that lend themselves directly to this application. In the first arrangement the movement of the pick-up is made to rotate a mirror which reflects a spot of light from a fixed lamp on to a long translucent scale, as is done in a mirror galvanometer. The second arrangement is to project the image of a scale that moves with the pick-up arm on to a fixed screen. With the former arrangement the scale length is virtually limited to that which can conveniently be carried in a straight line along the front of the desk though this can be extended, at the cost of some operational inconvenience, by the use of multiple mirrors giving a series of light spots one of which comes on to one end of the scale as another leaves the other. Another practical objection to this type of scale is that the light beam reflected from the mirror moves in an arc, and a large space which must embrace the whole length of the scale must therefore be kept clear of all obstructions. With the second arrangement neither difficulty arises for a scale of any length may be viewed on a screen of modest size which may be placed in almost any convenient position and, as the light beam is stationary throughout, it can readily be arranged to circumvent any obstruction. An optical system of this kind can therefore be built very compactly on to a turntable unit as the underside view in Fig. 6 shows. The general arrangement of the optical system is shown diagrammatically in Fig. 7.

The vertical spindle (1) of the pick-up is continued downwards below the mounting plate and it carries at its lower end a flat graticule (2) mounted in a horizontal plane. The scale on this graticule is in the form of a circular arc which subtends an angle of approximately 25° at the axis of the vertical shaft. A fixed beam of light from the projector lamp (3) is directed by a lens system (4) and (5) on to a mirror (6) which directs it downwards through the graticule. The light beam then passes through the projection lens (7) on to a mirror (8), which directs it towards the rear left-hand corner of the motor plate where another mirror (9) projects it upwards on to mirror (10) and thence on to the ground-glass viewing screen (11). This ground-glass screen is incorporated at the left-hand side of the lamp housing already mentioned and is shown as (3) in Fig. 1. An image of the scale on the graticule appears on this screen and movement of the pick-up causes it to move in the same direction past the fixed reference line on the screen.

For the reasons already given the scale divisions are arbitrary but it is desirable that the scale on each desk should give the same reading with the pick-up in the same position. To enable this adjustment to be made easily a calibrating groove is engraved on the perspex disk where it is normally covered by a rubber mat and the graticule is set so that the image reads 100 when the pick-up stylus is resting in this groove.

12. Amplifier Unit

The general arrangement of the amplifier section of one of these desks is shown in the block schematic of Fig. 8. The pick-up is connected directly to an equalizer which is arranged to present to it a high and capacitive impedance at low frequencies so as to minimize the effect of temperature changes on the pick-up. The equalizer gives an overall response characteristic in accordance with British Standard 1928:1955 which is also in accordance with the standards published in the U.S.A. as the N.A.R.T.B., the A.E.S., and the R.I.A.A. curves.

The equalizer is followed by a standard GPA/4 amplifier and an attenuator which can be adjusted in steps of 2 db over a range of 10 db to compensate for differing pick-up sensitivities. This attenuator is followed by a switchable

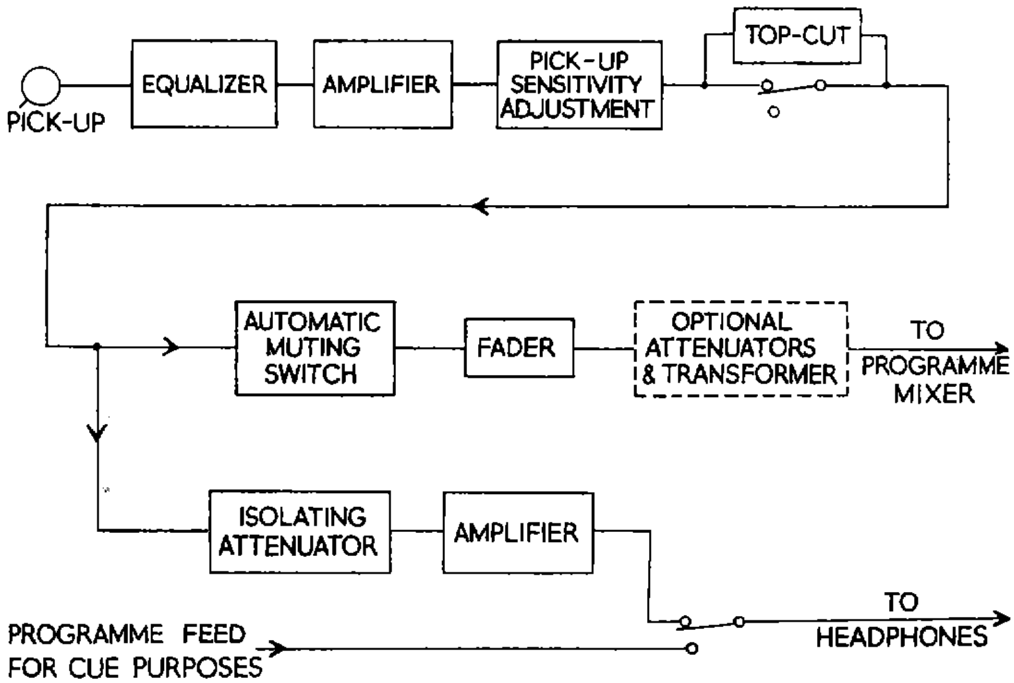

Fig. 8 — Block-schematic diagram of amplifier section

'top cut' circuit which can be inserted for records which have a high level of high frequency surface noise or distortion. From this point the circuit divides, one branch feeding the main fader via the 'muting' switch already mentioned, and the other branch feeding the 'pre-fade listen' amplifier.

The main fader, which can be seen as 8 in Fig. 1, is so arranged that as soon as it is moved from the 'off' position an auxiliary switch is operated which switches on a red light in the right-hand window of the lamp housing (9 of Fig. 1). The 'top-cut' switch can also be seen as 14 of Fig. 1 together with the key (15) which switches a pair of headphone jacks alternatively to the 'pre-fade listen' amplifier output or to an external cueing circuit.

The mechanical arrangement of the amplifier unit is shown in Fig. 2. The tray carries one mains unit and two identical amplifiers (GPA/4) which can readily be interchanged in emergency so that the 'pre-fade listen' facility is sacrificed rather than the main output from the desk. In front of the amplifiers can be seen the motor boosting unit which carries also the 'muting' relay (K2 of Fig. 5) and, to the left, the pick-up equalizer unit (EAT/12). The pre-set sensitivity adjustment can be seen in front of the motor boosting unit.

The front panel carrying the main fader, the 'top-cut' switch, and the 'pre-fade listen' key and jacks is hinged at its bottom edge to the front of the tray. The triangular panel brackets carry projecting pins at their outer ends and when the panel is folded back to the working position these pins engage in double ball catches one of which can be seen in Fig. 2. The panel is therefore held firmly in place but can be instantly folded downwards for servicing without removing the tray from the desk. Actually it is necessary to withdraw the tray an inch or so since when it is fully home special plates on the inside of the desk prevent the pins from leaving the catches. A padlock, which can be fitted to a hasp hidden underneath the hinged strip below the main panel, will therefore not only prevent the tray unit being withdrawn from the desk but will, at the same time, prevent access via the control panel.

It is difficult to make wooden desks with their sloping fronts all at precisely the same angle but the effect would be somewhat unsightly if the panels did not all fit snugly in place. It has therefore been arranged that the angle of the panel to its triangular brackets can be pre-set by pairs of locknuts and can be adjusted precisely to suit any desk carcass.

In a somewhat similar way an adjustment of the lid stays is provided so that the lids on a row of desks may readily be adjusted to stand open at the same angle without any unnecessary accuracy of manufacture being required. These desk lids, which are lockable, are also partially counterbalanced by springs so as to reduce the impact if they are dropped to the closed position.

The carcasses are simple wooden frames into which the turntable unit and the amplifier tray are inserted; they themselves carry no wiring. When a number of desks are to be connected together, a termination box is hooked on to the inside of the back panel of one of them, and from the box the leads to the other desks are taken. The mains supply to the motor is taken from one of a pair of mains sockets concealed behind the hinged strip below the control panel. The motor unit supply can therefore be readily unplugged from the mains and connected to a variable frequency supply if a large variation of turntable speed is desired. The other mains socket is provided so that when a number of desks are installed in a row each may derive its mains supply from its neighbour, only a single connection to the supply mains being required for the whole bank.

13. Reference

1. Berry, S. D., **Newly Developed Amplifiers for the Sound Programme Chain,** BBC Quarterly Vol. 4, No. 9 Summer 1954, pp. 111–22.

Summaries of some recent BBC Applications

PAT. APP. NO. 3127/55

COLOUR BALANCE CONTROL

Inventor C. B. B. WOOD

The statement of invention reads:
According to the present invention means for adjusting the colour balance of television signals in the form of two or more colour-separation signals comprise two or more level-control devices, each arranged to adjust the level of one of the colour-separation signals, a control member, and mechanical coupling means linking the control member to the two or more level-control devices, in such a manner that movement of the control member to increase the signal level controlled by one of the level-control devices, decreases the signal level controlled by the other level-control device, or at least one other of the level-control devices. The level-control devices may be potentiometers or other control means such as variable attenuators may be used.

The invention, in one application, is a simplified control for the adjustment of the balance between the colour-separation signals of a colour television system. The device provides a mechanical linkage between all the potentiometers controlling the individual levels of the colour-separation signals in such a manner that a continuous variation in hue is provided by a single control. Throughout the range of adjustment the overall brightness tends to remain constant.

PAT. APP. NO. 17619/55

NEGATIVE FEEDBACK TRANSFORMER

Inventors J. A. CHEW and D. E. L. SHORTER

The statement of invention reads:
According to the present invention, there is provided a transformer for use in a circuit employing negative feedback having main primary and secondary windings and auxiliary primary and secondary windings for deriving, for feedback purposes, a signal voltage substantially proportioned to, and in phase with, a signal voltage across one of the main windings, the auxiliary windings being upon the same core as the said one main winding and the auxiliary primary winding being connected in parallel with the main winding.

The invention is an improved form of transformer for use in amplifier circuits incorporating voltage feedback.

A RECENT BBC DEVELOPMENT

FERRITE MODULATOR

An experimental FM Test Oscillator embodying a ferrite modulator has been designed. This consists of a nickel-iron cored coil which carries the audio frequency modulation current. A Ferrox-cube cored coil placed in the gap forms part of the oscillatory tuned circuit.

A disadvantage of this type of modulator is that the mean permeability of the Ferrox-cube varies when the A.F. signal is applied and consequently the mean carrier frequency also varies. It is known that the mean carrier frequency variation can be reduced by working the Ferrox-cube at a higher flux density than would normally be employed. It has been found that the mean permeability and consequently the mean frequency variation can also be greatly reduced if the Ferrox-cube d.c. polarizing current is carried initially to saturation and then allowed to return to its normal operating value. This principle is used in the FM Test Oscillator in which it is arranged that the Ferrox-cube is initially saturated with a polarizing current of approximately 20 mA and subsequently operated with a current of 5 mA. This results in a very small change of mean permeability and in a much smaller change of the carrier mean frequency than would otherwise be experienced when the audio signal is applied.

*Published by the British Broadcasting Corporation, 35 Marylebone High Street, London, W.1.
Printed on Basingwerk Parchment in Times New Roman by The Broadwater Press Ltd, Welwyn Garden City, Herts.* No. 3378