Research Department REPORT No. C.012 3rd January, 1939

Serial No. 1939/2

Job No. 7.003.19

Work carried out by-
H. Davies
P.R. Terry

Drawings Nos.
C.012.1 to
C.012.6

GRAMOPHONE REPRODUCTION

TELEFUNKEN PICK-UP TYPE TO.1001

SUMMARY This report describes the results of tests carried out on the Telefunken pick-up type TO.1001 and specifies suitable correction circuits to be used with it.

Introduction

The Telefunken pick-up Type TO.1001 is generally similar to the earlier and now obsolete model TO.1001 but has a number of improvements in detail. It is of very original construction and is a marked departure from the usual rather stereotyped pick-up design. It is of the lateral moving iron type but of very small size. The general advantages of this type of construction will be dealt with in a separate report (No. C.013).

The top resonance, which in a good pick-up of the normal type may be as high as 6 or 7 KC, has been raised to the remarkably high figure of 14 KC. The pick-up has a permanent sapphire stylus

in place of the usual needles. It is of interest not only because of its original design but because it offers the possibility of a standard of reproduction not previously obtainable in lateral recordings.

Construction

In the Telefunken TO.1001 pick-up there is no needle or needle clamping screw. The armature consists of a very small strip of iron carrying a sapphire stylus at its lower end. The armature is carried in a vertical position, so that the sapphire axis is held perpendicular to the surface of the record. The armature is mounted on a V-sectioned strip of metal, presumably phosphor bronze, which provides the lateral elasticity and the longitudinal regidity required. There is no damping at all and, apart from the sapphire tip, the moving system is wholly metallic, so that deterioration with age is minimised. The magnetic system can be regarded as normal except for its very small size, the armature acting as a rocker pivoted in the lower gap. The scale of the design may be seen from the fact that the overall dimensions of the whole pick-up head are 15/16" x 3/4" x 5/8" and that it weighs only 1 oz.

The head is carried in a channel-sectioned tone arm with an offset end on which a hook is arranged so that the pick-up may

conveniently be raised and lowered with one finger. The sapphire has only a small projection below the head and, being located well beneath it, is not readily visible. To enable the sapphire to be placed in any required groove a white guide mark is inscribed on the vertical face of the head housing directly in line with it.

The tone arm is carried on two pairs of pivot screws, the horizontal axis being near the base board. A leaf spring is used to counterbalance some of the weight of the head and arm and to provide the correct pressure on the disc. This is only 30 grams, or approximately 1 oz. The tone arm also has spring loading in a horizontal plane which forces the arm in a direction outwards from the centre of the disc. The desirability of this outward thrust will be discussed later. It is necessary when mounting the pick-up not only to position the base correctly with respect to the turntable spindle but also to locate the two fixing screw holes, since rotation of the base varies the tension of the horizontal spring. The mounting is easily accomplished with a template. The underside of the head should be parallel to the surface of the disc and as the projection of the sapphire, and therefore the clearance of the head, is small, the height of the pick-up must be accurately adjusted by means of the packing rings provided.

The pick-up head and the sapphire stylus are necessarily fragile and would be damaged if the head were to be dropped on to the disc from any height and a safety device is therefore provided. This consists of a small roller, with a horizontal axis, mounted immediately behind the head. The roller is lightly spring loaded and a segment is cut away leaving a relatively large flat which normally faces upwards. The cylindrical surface projects downwards a little below the tip of the sapphire, so that when the pick-up is lowered on to a disc it is the surface of the roller which first makes contact. Friction then causes the roller to rotate with the moving disc surface, and against the control spring, until the flat surface is downwards, in which position the roller projects less than the sapphire, which is thus automatically lowered on to the disc. The device provides good protection against rough handling, but has certain disadvantages which will be discussed later.

The distance from the centre of the tone arm mounting circle to the stylus tip is 8", and the offset angle is approximately 22°. The tone arm, normally mounted, will clear discs up to 13" diameter. The weight of the complete pick-up and tone arm is only $6\frac{1}{4}$ oz. as compared with 14.3/4 oz. for a B.T.H. needle armature pick-up or over 4 lbs. for an E.M.I. High Fidelity pick-up having

a shorter tone arm.

Electrically the pick-up has a low impedance and would normally require a load of about 600 ohms. It is quite possible, therefore, to feed the pick-up directly into a 600-ohm line and to locate the correction unit at a remote point, if this should be desired. A step up transformer would normally be provided before the first amplifier.

Performance

Fig.1 shows the frequency characteristics of the pick-up on pressings as obtained by the variable disc velocity method, which will be discussed in a separate report (No. C.013). Fig.1 gives the output voltage of the pick-up in db. absolute per 1 cm/sec. alternating velocity with various load resistances. With a load of 600 ohms the frequency characteristic is seen to be smooth and essentially flat from 50cycles/sec. to 10 KC. The characteristic rises at each end to the two main resonances and there is a small resonance at about 300 cycles/sec. The frequency characteristic is remarkably good for a pick-up.

The impedance varies from 100 ohms at 100 cycles/sec. to 250 ohms at 8 KC. As indicated in Fig.1 the use of a load resistance of less than 600 ohms reduces the output voltages and causes the characteristic to fall a little at the higher frequencies.

With a 600-ohm load the sensitivity is about -40 db. absolute per cm/sec. at 1 KC. This means that on normal commercial recordings peak voltages of about -20 db. absolute will be delivered across the load. The makers supply a step up transformer with a turns ratio of 1/14 for connecting the pick-up direct to an amplifier. Using this the amplifier input voltage would therefore peak to about +3 db. (absolute).

Since normal commercial recordings are made with an attenuation of 6 db. per octave below 250 cycles/sec. it is necessary to include a corresponding bass tip in the reproducing chain and in this respect the slight increase of sensitivity of the pick-up below 100 cycles/sec. is helpful. The insertion of a simple single stage bass tip will produce a general loss of about 16 db. with a frequency characteristic having a maximum divergence from the inverse of the nominal recording characteristic above 60 cycles/sec. of 3.5 db. at 250 cycles/sec. A greater attenuation will be necessary if the shape of the curve is to approximate more closely to the theoretical. It is often convenient to insert the bass tip circuit between the pick-up and its amplifier rather than to place it in the amplifier itself, and this procedure will, of course, reduce the input voltage level. A circuit of this kind suitable for general use is given in Section 4 of this report.

In order to show the form of the top resonance of the pick-up the response up to 16 KC is given in Fig. 2. This was obtained by the variable disc velocity method using a commercial tone disc and with a pick-up load of 600 ohms. The resonance occurs at 13.5 KC and, as would be expected from the absence of damping, it is very sharp. On cellulose discs the resonance is a little higher in frequency. The bass, or tone arm resonance, occurs at about 25 cycles/sec. and there is therefore the unusually wide range of over 9 octaves between the main resonances. Some ten specimens have been examined and the frequency characteristics have been found satisfactorily consistent.

An interesting point in the performance of this pick-up is its response to surface noise. With normal pick-ups it is necessary to provide considerable attenuation at 6 - 7 KC if the surface noise is to be kept within reasonable limits. In this case no damping is provided for the top resonance and with a 600-ohm load the frequency characteristic is slightly rising up to 10 KC so that it might well be expected that in this condition surface noise would be quite intolerable. Actually this is not the case. On good specimens of commercial records the surface noise, when using a frequency characteristic as shown in Fig. 2, is not excessive and is, in fact, of much the same order as is usually obtained with

a sharp cut off at about 6 KC. On some commercial recordings, of course, there are components of surface noise at quite low frequencies and these are reproduced by the Telefunken pick-up just as any other signal is. Its particular virtue is in the elimination of the high pitched "record hiss" normally associated with a pick-up amplifier chain having any considerable response above 5 KC. The production of the hiss is evidently due to shock excitation of the top resonances, and the trouble is largely removed if the top resonance is sufficiently high in frequency.

The impossibility of giving an adequate description of the harmonic distortion of a pick-up by any simple figures will be indicated in Report No. C.013. Extensive listening tests have therefore been made on the Telefunken pick-up playing good and bad commercial recordings and special cellulose recordings and with a variety of frequency characteristics. It has been found that the reproduction is usually clean and free from high frequency buzzing. With a good high frequency response the difference between a good and a bad recording and between a worn and an unworn disc is, of course, more apparent than when top response is lacking, but on the better recordings the Telefunken has been found to give results superior to any other pick-up yet tested.

With high quality recordings it is possible to obtain

unusually clean reproduction extending with no serious loss up to 10 KC, with reasonably low surface noise and without the use of "scratch filters" or any sharp cuts in the frequency characteristics. Experiments with special cellulose recordings have, in fact, shown that the pick-up itself is capable of a very high standard of reproduction. With commercial recordings the quality will be limited by the recordings themselves and, in general, it will not be practicable to make full use of the possibilities offered by the pick-up. Nevertheless even with a frequency characteristic rather drastically curtailed to accommodate bad recordings the general performance on the better ones is sufficiently superior to that normally obtainable to justify the use of the pick-up whenever practicable.

The use of a "permanent" sapphire stylus in place of the usual needle has both advantages and disadvantages which are discussed later. The makers claim for the sapphire a life of about 5,000 disc sides before it becomes as much worn as a steel needle after playing one side. After 2,000 sides the top response is said to have dropped by $1\frac{1}{2}$ db. at 10 KC. Life tests have not been carried out since, in the absence of special automatic gear, they would be extremely laborious, but the figure of 5,000 disc sides seems reasonable. On cellulose discs the life would be much

longer. When the sapphire becomes excessively worn a new sapphire-spring-armature unit can be inserted. The operation is not a particularly easy one but is as simple as can be expected in a unit of such small size.

Owing to the light weight of the pick-up and the small control forces record wear is appreciably reduced as compared to normal pick-ups. The makers' claim of five times the number of playings before deterioration is observed is perhaps rather high on pressings. Obviously no precise figure can be given but a life of 100 playings may be expected on most commercial discs, as against about 30 playings with a normal pick-up, though either of these figures may, of course, be appreciably exceeded in some cases. On cellulose discs the average figure of five times the normal number of playings can be accepted.

Correction Circuits

Fig. 1 shows that the output voltage is very nearly proportional to the velocity on the disc from 50 cycles/sec. to 10 KC. Nevertheless in normal use correction circuits are required for four reasons. Firstly it is normal practice in commercial gramophone recordings to attenuate 6 db. per octave below 250 cycles/sec. Secondly it is usual in commercial recording to over-emphasise the higher frequencies. Thirdly, on any but the very best

discs it is desirable, in any case, to reduce the high frequency response a little in order to reduce surface noise, and fourthly, since the recording of the higher frequencies on some discs is exceedingly bad the reproduction of these at the proper level would be intolerable and the high frequency response should therefore be heavily cut. For these reasons it is necessary to attenuate the higher frequencies and to boost the lower ones. It may be noted that a small amount of top cut will be required on all commercial recordings but a large amount will be required only on bad ones.

Without allowing for the slight increase of pick-up sensitivity below 100 cycles/sec. the bass tip required is 7 db. at 100 cycles/sec. and 13 db. at 50 cycles/sec. For general use a rough approximation to the ideal shape of curve is quite sufficient but it will usually be important to have the minimum of attenuation. A suitable correction circuit for insertion between the pick-up and a straight amplifier is shown in Fig. 3. A "tone control" is included so that the high frequency response may be adjusted for each disc if desired. Without the tone control a frequency characteristic sensibly flat up to 10 KC is obtained. The tone control resistance may be made of a higher value than that shown but with a steep grading; 5,000 ohms 10% are suitable figures.

When playing commercial discs the peak level on the

transformer primary will be about -36 db. absolute. With a Telefunken transformer the secondary voltage will peak to about -13 db. If a transformer with a different turns ratio is used the secondary load should be such that the correction circuit is terminated by an impedance of not less than 1,000 ohms. If a separate volume control is required or if the output level from the pick-up is excessive a potentiometer may be used on the secondary side of the transformer.

For service use a different form of correction (or G) unit is required. The unit is to be inserted between the pick-up and an A amplifier input and consequently a considerable attenuation is permissible. On the other hand the A amplifiers have a frequency characteristic falling steeply at the bass and rising at the top, and this must be compensated in the G unit. The total bass tip required is 9.5 db. at 100 cycles/sec. and 16.5 db. at 50 cycles/sec., allowing for the rise of about 2.5 db. at 50 cycles/sec. obtained from the pick-up itself.

A bass tip so steep as this necessitates considerable attenuation if the correction unit is to contain only resistances and condensers, as is desirable. Moreover, a certain amount of attenuation in the output circuit is unavoidable since the closing impedance may vary due to a microphone or another G unit being faded

up across the same A amplifier input, and this must not affect either the frequency characteristic or the output level too seriously. It has been found possible, however, to meet these requirements without exceeding the permissible attenuation and using only resistances and condensers, though the latter are necessarily of rather large values.

To determine the top cut required for service use a compromise is necessary. On good records it is desirable to have a frequency characteristic falling only a little to 8 KC but, on the other hand, bad discs will sound less unpleasing if the high frequencies are very vigorously cut. It is not considered practicable to adjust the response manually to obtain the best condition for each disc individually, and it is necessary to choose a frequency characteristic which is an optimum compromise for the range of discs used. The reproduction of good records will therefore be made less good than is possible in order to make bad discs sound more tolerable. If it could be ensured that very inferior discs were not used for transmission then the frequency characteristic compromise could be re-adjusted to the advantage of the better recordings.

Listening tests were made to a selection of poor discs, the frequency characteristic being in each case adjusted to give as

satisfactory reproduction as was possible. As a result of these tests the form of top cut was decided. Up to 4 KC it is similar to that used at present with B.T.H. pick-ups but above that frequency the cut is much less rapid. The attenuation is smooth and gradual and there is no form of "scratch filter" or resonant circuit. The G unit has been designed so that the magnitude of the top cut may be varied should this be found advantageous in the light of further experience under service conditions.

Fig. 4 shows the frequency characteristic of the G unit with three top cut adjustments when terminated with 300 ohms, and Fig. 5 gives the overall response of the pick-up - G unit - A amplifier chain. It shows the A amplifier output when reproducing a standard H.M.V. Glide Tone disc. Fig. 6 shows the circuit of the unit. A small attenuator with a constant output impedance of 300 ohms and adjustable in steps of 4 db. is included in each unit to enable the output level to be adjusted.

Discussion

The Telefunken has several advantages over the more normal type of pick-up. The pressure on the disc is only 1 oz. as compared with 2.5 oz. on the counterweighted B.B.C. pick-ups and 4 to 5 ozs. on most commercial models. This not only reduces record wear but it also reduces the load on the turntable motor and thus

improves the constancy of disc speed. This consideration is more important with cellulose discs than with pressings. The force required to deflect the stylus point is of the order of 10% of that usually required so that again record wear is minimised.

The unusually wide range of 50 cycles/sec. to 10 KC. is available free from any serious resonances. With a given high frequency response the surface noise produced on good discs is unusually low though on discs with bad surface noise extending into the lower frequencies the pick-up has, of course, no marked advantage in this respect. Reproduction is unusually clean and with suitable recordings a standard far beyond that normally associated with gramophone records can be obtained.

There is no needle to require replacement and no needle clamping screw to be overturned, bent or lost. Moreover no trouble can arise due to playing discs with the needle not properly clamped and loose in its socket while the playing of discs with excessively worn needles could only occur after long intervals of use and can easily be guarded against. There is no effective change in the size of needle point during a whole recital. The pick-up contains no rubber and as the moving system is controlled entirely by metal there is the very marked advantage of negligible deterioration with age. For these reasons therefore a high standard

of consistency and, short of accidental damage, of reliability, is to be expected.

The main disadvantages of the Telefunken pick-up are summed up in the one word "fragility". Owing to its small size it is necessarily somewhat delicate, and of course the sapphire stylus, if damaged by misuse, is not so readily nor so cheaply replaced as is a normal needle. Nevertheless the fragility of the pick-up may be exaggerated. It will certainly not stand being banged about but if treated with reasonable care no breakages occur. A number of these pick-ups are known to have survived considerable use in non-technical hands without damage and they therefore appear to be quite robust enough for reasonably careful domestic use. Whether they are sufficiently robust for service conditions remains to be seen.

The pick-up has the positive virtue that unusually small forces are required to drive the stylus point. This, however, means that the maximum permissible side thrust on the pick-up is correspondingly reduced. For this reason it is unsuitable for use with most forms of automatic stop and automatic record changing mechanisms, since they usually involve considerable side pressures. Similarly the pick-up is not suitable for use on existing parallel tracking arms though handling mechanisms of a suitable scale could

no doubt be developed.

It has been mentioned in Section 2 of this report that the tone arm of the Telefunken pick-up is spring loaded in an outward direction. On any pick-up having the head offset to minimise tracking errors there is a force pressing the needle against the inner groove-wall, because the frictional force at the point of contact with the disc is in a direction more or less tangential to the groove and therefore has a turning moment about the vertical pivot of the tone arm. It is for this reason that a pick-up which jumps out of the end groove on the inside of a disc runs violently in towards the centre. This inward thrust, which does not of course occur with a parallel tracking mechanism, can be approximately balanced by a spring forcing the pick-up outwards. Such compensation would only be approximate since the spring tension would increase as the pick-up approached the centre of the disc whilst the frictional drag would decrease. In the Telefunken pick-up the spring tension is such that at the outer edge of the disc the stylus presses on the outer wall of the groove. The frictional drag is thus definitely overcompensated at all radii. The main purpose of the horizontal spring is apparently to ensure that at the inside of the disc the stylus remains pressed against the outer wall of the groove and so the pick-up has no tendency to leave the groove

and run inwards. Were this to occur the sapphire would run on to the label and the pick-up would most probably be seriously damaged.

But although very useful for this purpose the spring loading has certain disadvantages. If a normal pick-up is lowered on to the plain outer edge of a disc it will either remain where it is or move inwards into the first groove because of the frictional drag. On the Telefunken, however, the spring presses the arm outwards and as soon as released the pick-up slides outwards off the disc. This is likely to cause serious damage, particularly if the edge of the disc is chipped or if it is of small diameter so that the pick-up drops on to the cloth-covered turntable. It is therefore important to ensure that the stylus has entered the first groove before the pick-up is released.

Particular danger arises in the case of discs recorded from inside to outside which are often without a play-off groove. At the end, therefore, the stylus rises up a ramp on to the plane polished edge and the spring then forces it outwards off the disc.

Apart from use with discs recorded from inside to outside, which will not occur in normal practice, no difficulty has been experienced in starting the pick-up at the outer edges of a disc. Should it prove necessary, however, the spring loading may be modified so as to force the pick-up always to a position corresponding

to a disc radius of, say, $3\frac{1}{2}$ inches. This would ensure that the pick-up was loaded inwards on the outer grooves and outwards on the inner grooves, thus ensuring safety at both ends. Such a procedure would increase the total inward thrust at the outer edge and is, moreover, a modification not very readily applied. It is therefore to be avoided if possible.

The spring roller safety device is found to operate on the whole successfully provided that its movement is not hindered by dirt or grease on its spindle. Its worst fault is that if lowered on to the inner part of a disc it will sometimes fail to operate altogether. If the pick-up is entirely released it will then slide very slowly outwards until a greater diameter has been reached and the roller will then operate and lower the pick-up. In service this should not be any disadvantage except for certain kinds of Effects work for which a mechanical groove-locating and pick-up lowering device would in any case be desirable. For the normal use to which it would be subjected in recitals and similar work the roller has been found to be satisfactory. An operator with any delicacy of touch and used to using relatively delicate mechanisms would no doubt prefer to be without the roller and to avoid the jerk unavoidable with such a device, but its utility as a safeguard against carelessness or accident justifies its retention under service conditions.

The only two demands upon the operator's attention are that the pick-up should not be released until the stylus has entered the first groove and that no side pressing should be put on it when playing a disc. It should be raised and lowered with a simple vertical movement.

If a Telefunken pick-up is to be used to play cellulose discs which have received a vaseline treatment, a sealing strip is required underneath. Otherwise the blob of vaseline which inevitably collects round the stylus attacks the rubber sealing disc which is mounted inside the case. It is very undesirable to remove this case since it is held in position by four aluminium flaps bent over and these will readily break off. A strip of very fine oiled silk perforated for the stylus and stuck to the under face of the head has been found satisfactory. It is readily applied without any kind of dismantling. Protection of this kind is not, of course, required for playing pressings. An occasional touch with a soft camel hair brush to remove any fluff which may have collected round the stylus is sufficient.

Conclusions

The pick-up is of the moving iron type (lateral) but is very small in size and light in weight and has a permanent sapphire stylus. The frequency response is unusually good, the top

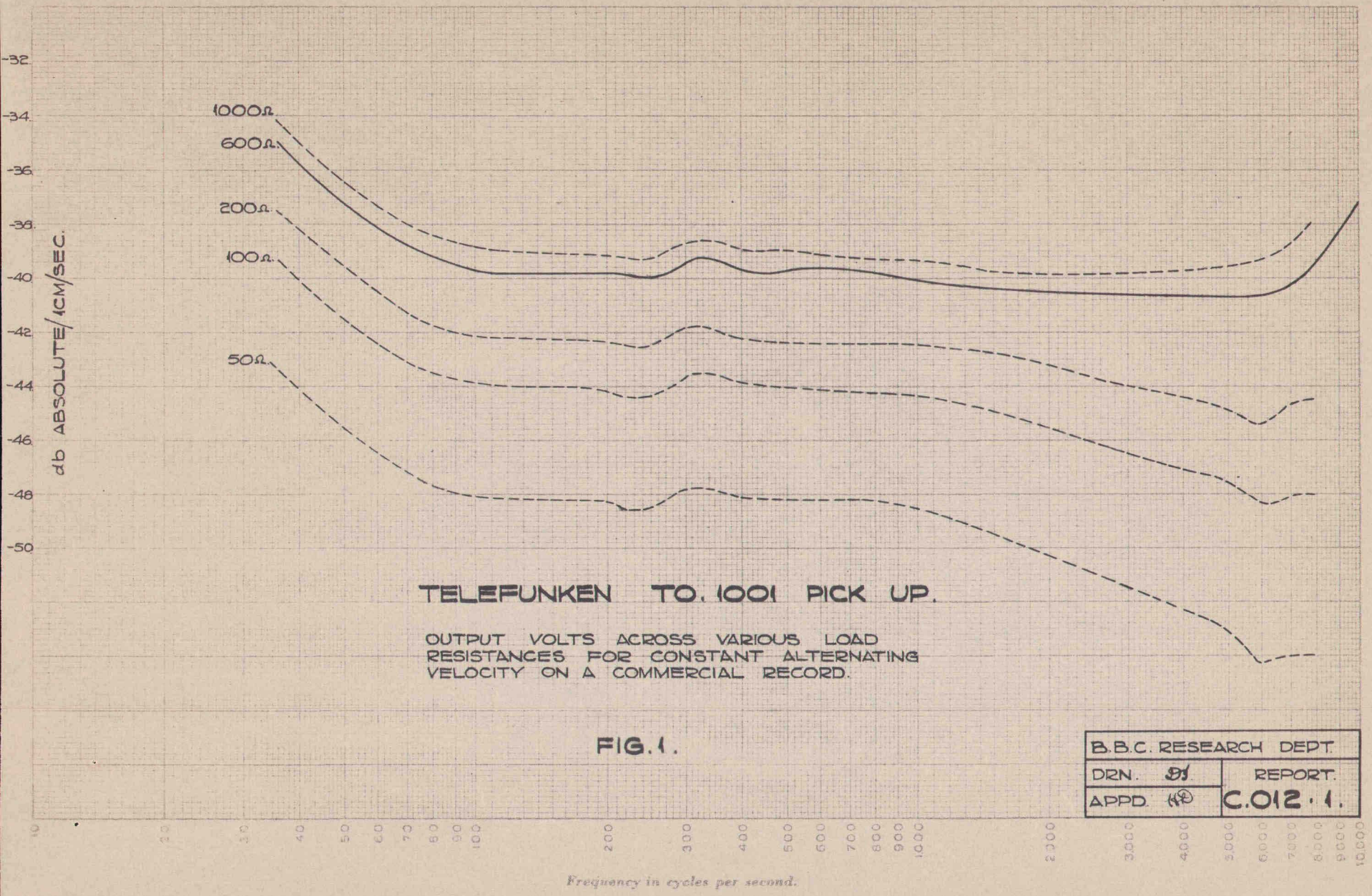
resonance being an octave above that of a good normal pick-up. Amplitude distortion is low. The pick-up offers a standard of reproduction not hitherto possible on lateral cut discs. The full benefit of this is, of course, only obtainable with good recordings, but even with a frequency characteristic much the same as that at present used there is still a definite improvement in the reproduction of the better discs.

Record wear and the load on the gramophone motor are much lower than usual and there are no needles to replace. The moving system has no rubber damping and is entirely metallic so that the pick-up should be remarkably free from deterioration.

On the other hand the pick-up is relatively fragile and requires more care in operation than does the normal type. It is not suitable for use with existing groove locating units or with most automatic stop and automatic record changing mechanisms and should not be used without modification on discs cut from inside to outside.

H L Kirke

HD/IMT



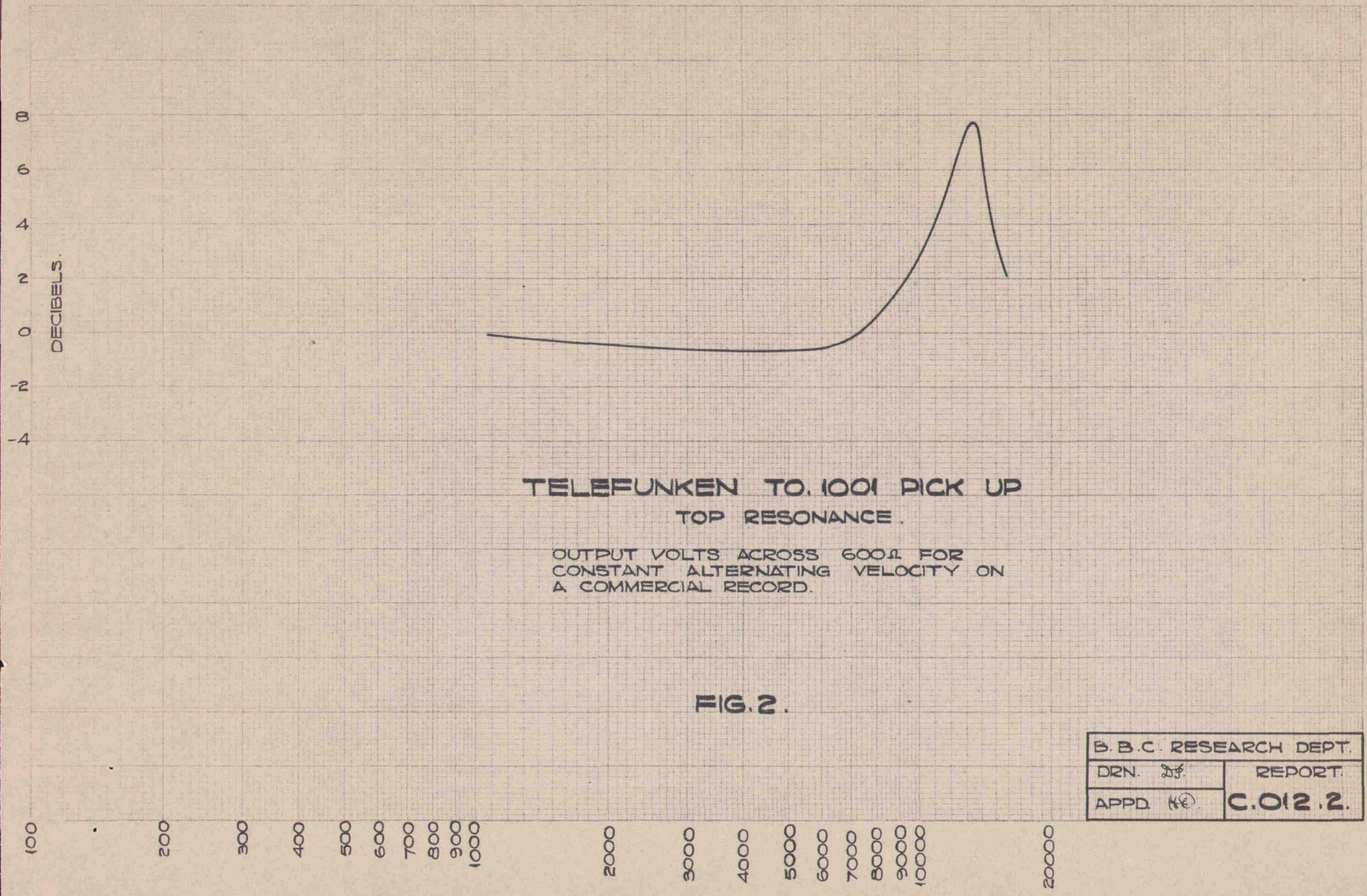
TELEFUNKEN TO.1001 PICK UP.

OUTPUT VOLTS ACROSS VARIOUS LOAD RESISTANCES FOR CONSTANT ALTERNATING VELOCITY ON A COMMERCIAL RECORD.

FIG.1.

B.B.C. RESEARCH DEPT.	
DRN. DJ	REPORT.
APPD. HD	C.012.1.

5-1-39.



TELEFUNKEN TO.1001 PICK UP

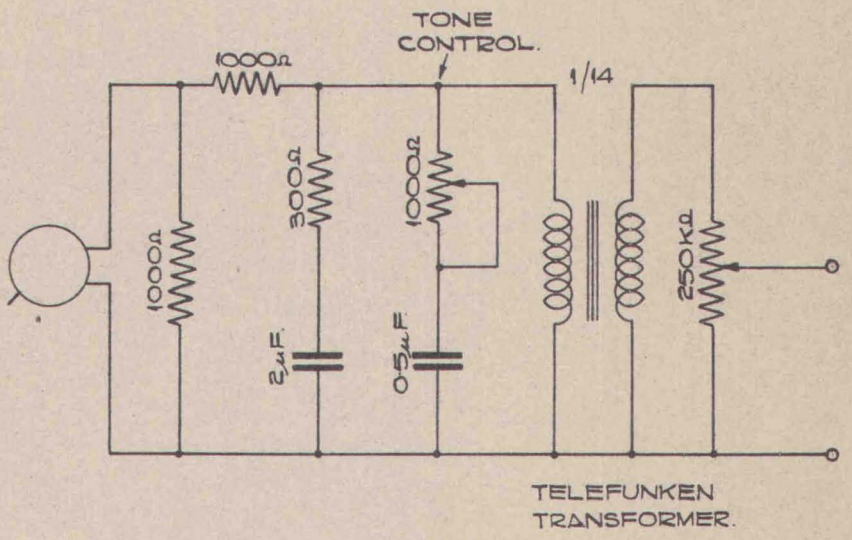
TOP RESONANCE.

OUTPUT VOLTS ACROSS 600Ω FOR CONSTANT ALTERNATING VELOCITY ON A COMMERCIAL RECORD.

FIG.2.

B.B.C. RESEARCH DEPT.	
DRN.	REPORT.
APPD.	C.012.2.

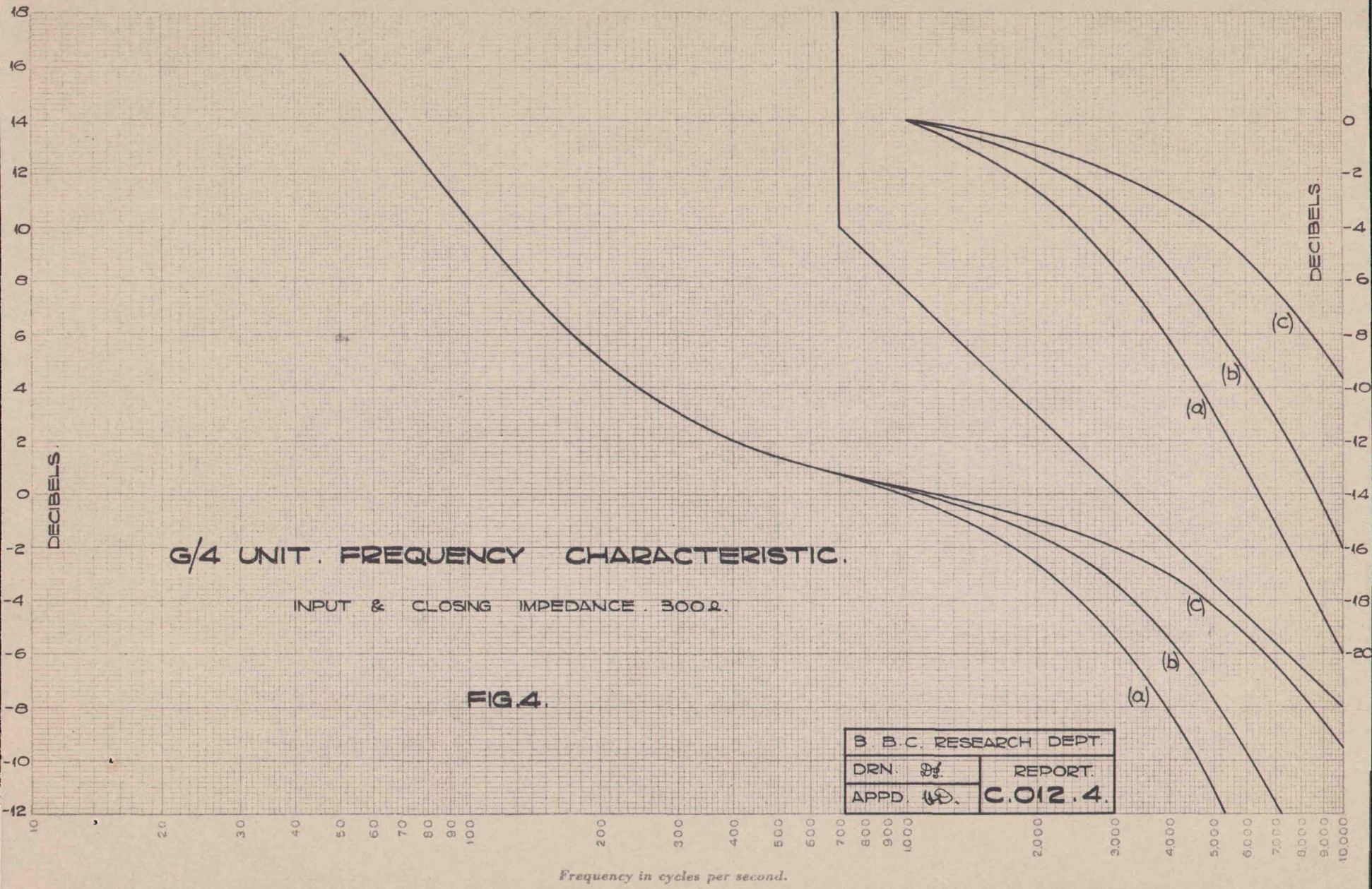
5-1-39.



SIMPLE CORRECTION CIRCUIT.

FIG. 3.

TELEFUNKEN TO. 1001 PICK UP.	B. B.C. RESEARCH DEPT.	
	DRN. DJ.	REPORT.
	APPD. HD.	C.012.3.



G/4 UNIT. FREQUENCY CHARACTERISTIC.

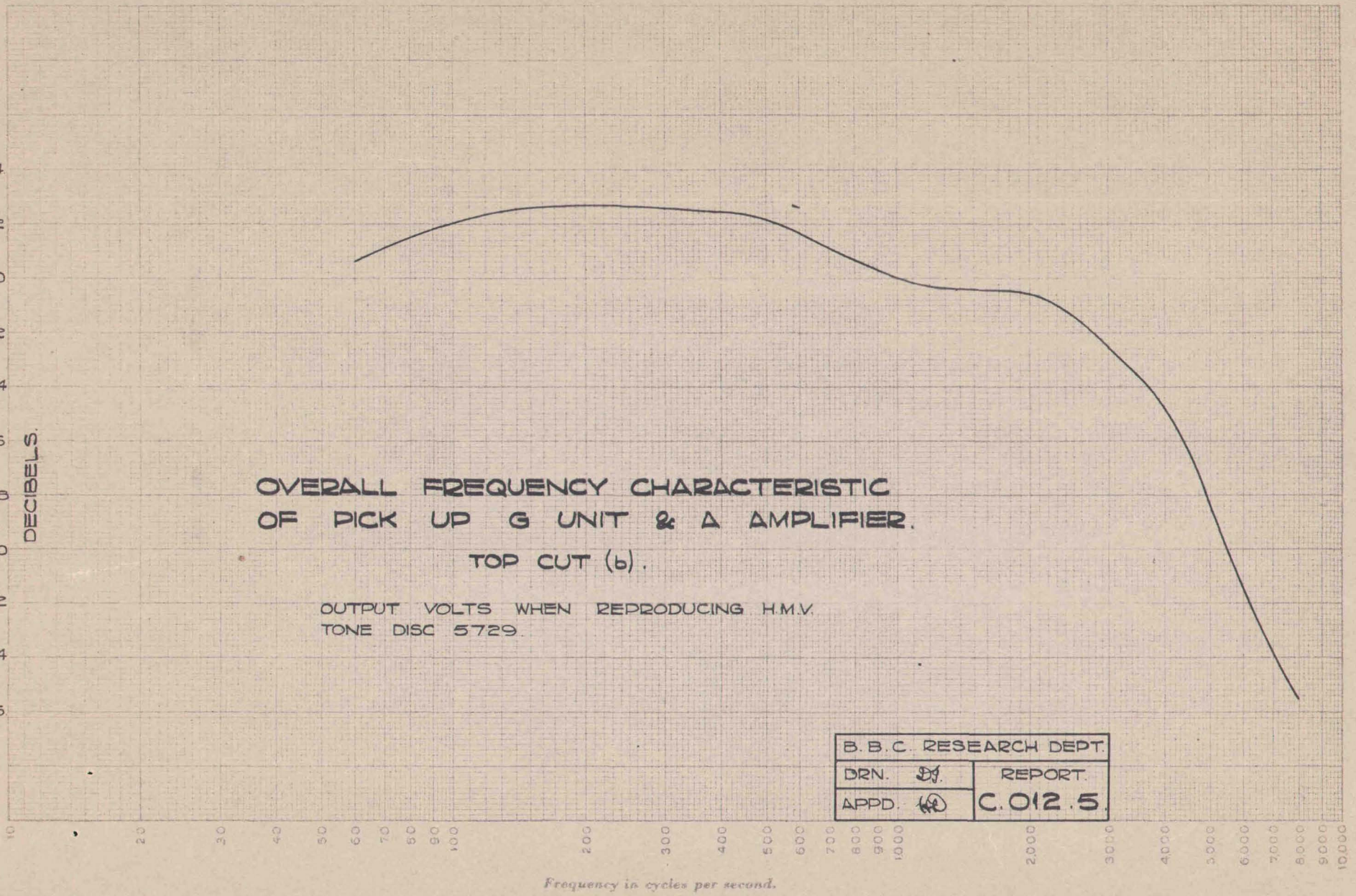
INPUT & CLOSING IMPEDANCE. 300Ω.

FIG.4.

B.B.C. RESEARCH DEPT.	
DRN.	REPORT.
APPD.	C.012.4.

Frequency in cycles per second.

6-1-36.



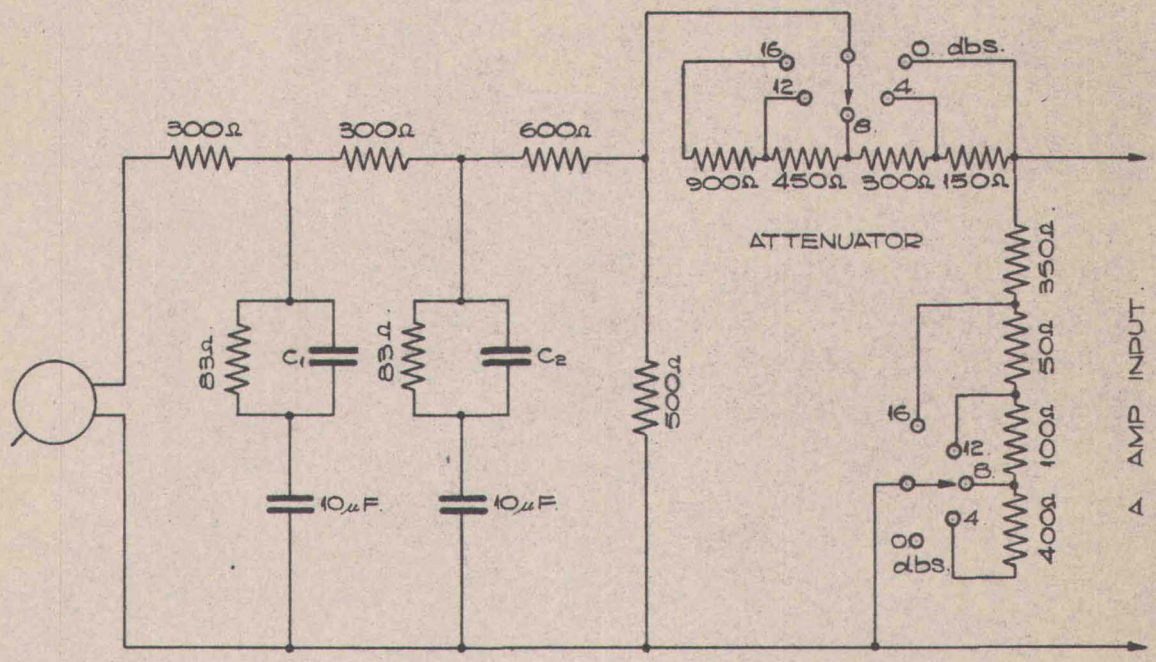
OVERALL FREQUENCY CHARACTERISTIC OF PICK UP G UNIT & A AMPLIFIER.

TOP CUT (b).

OUTPUT VOLTS WHEN REPRODUCING H.M.V. TONE DISC 5729.

B.B.C. RESEARCH DEPT.	
DRN. DJ.	REPORT.
APPD.	C.012.5.

6-1-39



G/4 CORRECTION CIRCUIT.

	C_1	C_2
(a).	1·0μF	0·75μF.
(b).	0·5μF	0·75μF.
(c).	0·5μF	0·25μF.

FIG. 6.

TELEFUNKEN TO.1001.
PICK UP.

B.B.C. RESEARCH DEPT.
DRN DJ.
APPD HD.
REPORT. C.012.6.