No. 37

MANUAL OF DIRECT DISC RECORDING

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BERNARDS (PUBLISHERS) LTD.
The GRAMPIANS · WESTERN GATE · LONDON. W.6

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PREFACE

This book is the first to be published in Great Britain dealing specifically with direct disc recording and, although primarily an introduction to the subject, the comprehensive list of references will enable the advanced amateur and professional recordist to consult original literature (to whose authors and publishers grateful acknowledgment is made here, in the bracketed references throughout the text, as sources of information), which describe in detail what can only be referred to briefly in this handbook. Those items and references in this manual of particular interest and use to the beginner have been indicated by asterisks.

1943. D.W.A.

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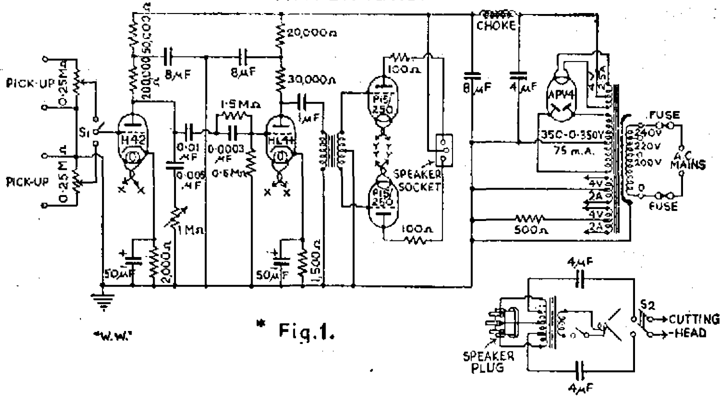
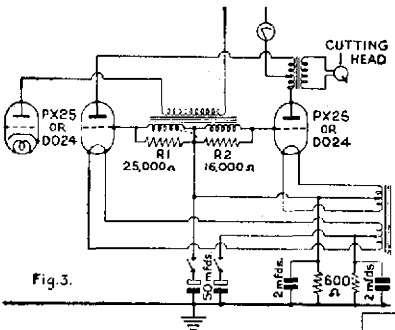


*Fig. 1.—Complete circuit of 4 to 6 watts recording Amplifier (Ref. 8).



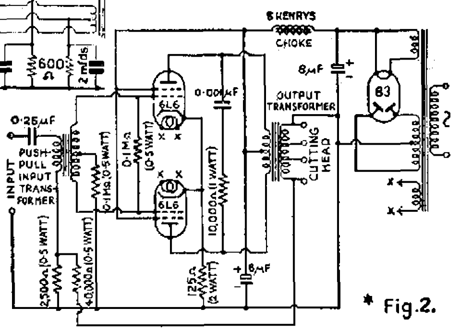


*Fig. 2.—Add-on inexpensive 12 watts recording amplifier, using 6L6's in push-pull, with negative feed-back. (Ref. 2).

Fig. 3.—High-quality 10 to 12 watts push-pull recording amplifier output stage, using negative feed-back frequency correction, with switching to restore amplifier characteristic to linear form for play-back. (Ref. 44).

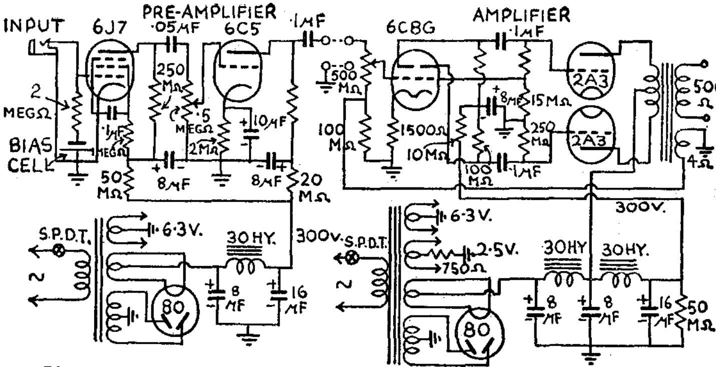


Fig.4. (M - 1,000Ω)

Fig. 4.—Complete circuit of 10 watts recording amplifier, with pre-amplifier, using American- type valves. (Ref. 36).

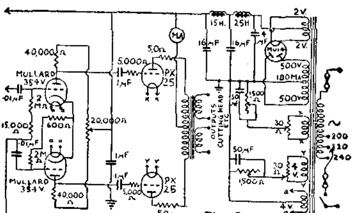


Fig.5.

Fig. 5.—High-quality 12 watts recording amplifier, with improved paraphase push-pull circuit. Recommended for use in conjunction with pre-amplifier circuit, Fig. 29. (Ref. 5).

AMPLIFIER HARMONIC DISTORTION AND POWER OUTPUT CHARACTERISTICS.

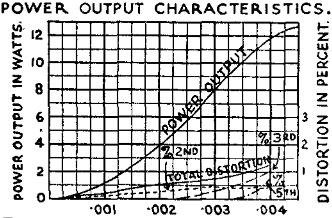


Fig.6. E SIG. TO AMPLIFIER IN R.M.S. VOLTS.

Fig. 6.—Harmonic distortion and power output characteristic of high-quality recording amplifier. Total harmonic distortion is less than 1 per cent. at 10 watts output.

*BASIC RECORDING CHARACTERISTICS.

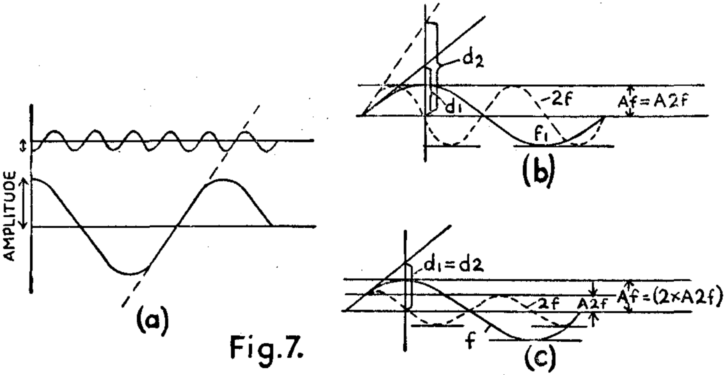


Fig.7.

Fig. 7a.—In a sine wave the slope in the region of the datum line represents the velocity of the moving point (which can be regarded as the cutting-stylus or needle-tip). Velocity is a product of amplitude times frequency, so that to maintain a constant slope, the amplitude must be progressively increased as the frequency is decreased.

Fig 7b.—A graphical representation of constant amplitude recording containing two frequencies, one of which is twice the frequency of the other. With this type of recording the maximum slope of the wave is proportional to the frequency. Thus the distance d_2, which is proportional to the slope of the higher frequency, is exactly twice the value of d_1, which is proportional to the lower frequency. For higher frequencies the slope is proportionately greater. The maximum lateral velocity of the stylus is attained as it crosses the centre of the groove, i.e., zero axis, and at this point the slope is obviously greatest. This constant amplitude recording characteristic is essentially that of the crystal type cutting-head.

Fig. 7c.—Two frequencies of constant velocity (or slope) are shown, the frequency of one being the frequency of the other. In constant velocity recording, the slope of the wave at the zero axis is constant for a constant driving power, and the amplitude is inversely proportional to the frequency. Therefore, the height of d_2 of the higher frequency is as half of the height d_1 of the lower frequency, but the slope at the axis remains the same. Similarly, for higher frequencies, the amplitude is proportionately less for the same power output. This characteristic is essentially that of the electro-magnetic cutting-head. (Ref. 21).

Fig. 8.—Illustrates the principle of the optical method of measuring velocity/amplitude on gramophone records, due to Buchmann, Meyer and Just, and so named after them. The curved line ABCDE at the top of the figure represents the side of a groove, in a sinusoidal

section, of the disc material. Parallel light (a point source) falls upon it and is reflected. The largest angle, γ, between an incident and reflected ray, occurs at the inflection (bending) point of the curve. If OO is the time axis (or the groove-width), the curve

BUCHMANN-MEYER EFFECT

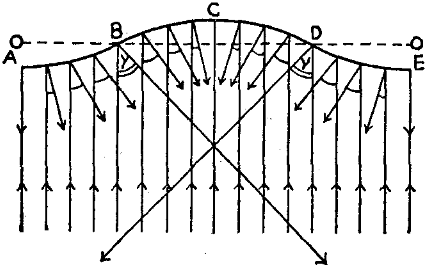


Fig. 8.

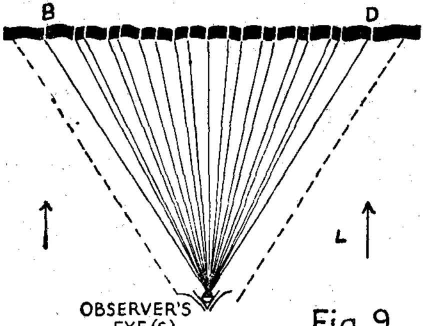


Fig. 9.

ABCDE depicts the displacement, so that γ is given by dx/dt, which is the velocity/amplitude, or lateral velocity, etc. No larger angles than γ are possible. In Fig. 9 a number of reflected rays is shown. The outermost ones radiate from the points of inflection. A luminous band can be seen if the line BD is moved along its continuation so that the reflecting spots dissolve into each other. The width of the light band is determined only by the velocity/amplitude of the curve, and is independent of the position of the observer's eye(s). When the line OO is a circle, i.e., a groove, on a disc, the same result is obtained. (See Ref. 180). Also Figs. 22-24.

Fig. 10.—Method of checking noise generated in cutting record groove. Control of surface-noise, given high-quality electro-mechanical equipment, resolves itself into a systematic quality control of

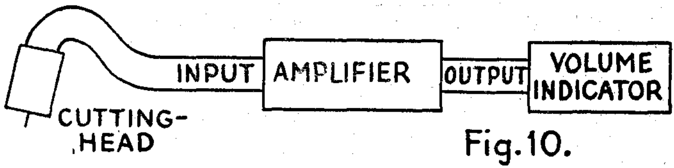


Fig.10.

styli and blanks. In the scheme shown here, the cutting-head is used to generate a voltage while making a plain-cut, i.e., an unmodulated groove. The rougher the cut, the greater the vibration of the stylus tip, and hence the greater the voltage produced and the V.I. reading. In this manner, a simple method of measuring smoothness and quietness of cut is obtained, which is also an invaluable way of checking the edge of styli, as even the best lapidaries do not turn out sapphires of completely uniform quality. This method can also be used to check and compare blanks as an acceptance test for large batches. (Ref. 29.) Another simple and quick method of measuring surface-noise is by means of a noise-meter having a frequency-weighting network and a damped meter of the V.I. type.

COMPLETE DISC RECORDING, PRESSING AND REPRODUCING SYSTEM.

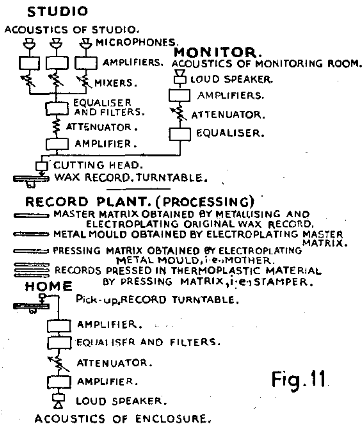


Fig. 11

*CUTTING-HEAD COUPLING OR MATCHING CIRCUITS. (CRYSTAL).

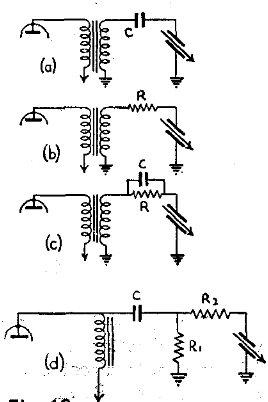


Fig. 12.

Fig. 12. — Coupling circuits for crystal cutting-heads, with equalisation inserted between output circuit and head. Fig. 12a is simple direct connection; C=0.01 to 0.05 μF., or approximately the same value as that of the crystal element. Fig. 12b represents an elementary equaliser, enabling almost any desired curve between constant amplitude and constant velocity to be obtained. R=10,000

to 50,000 ohms. Fig. 12c is circuit to obtain recording characteristic in which below a cross-over frequency of 300 to 500 c/s., as well as above 1,000 to 2,000 c/s., the response is flat (constant amplitude), but the middle portion has a constant velocity slope of 6 db. per octave. C=0.001 to 0.05 μF.; R=10,000 to 50,000 ohms. A step-down transformer, which gives the required voltage, i.e., 75 to 150, plus any drop in the equaliser network, is used, with the three foregoing circuits, to keep the series impedance as low as possible. Fig. 12d is a circuit omitting output transformer and using coupling choke instead. C=0.1 to 0.5 μF.; R_1—50,000 to 150,000 ohms, and R_2=1 megohm. Only satisfactory when used with triodes, unless negative feed-back is incorporated. (Ref. 17).

*CUTTING-HEAD COUPLING OR MATCHING CIRCUITS. (ELECTRO-MAGNETIC).

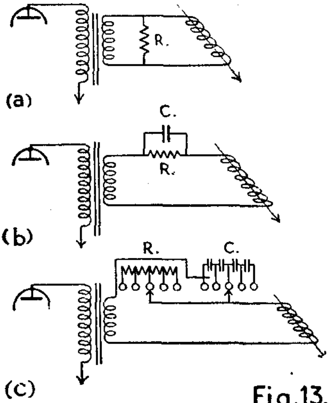


Fig.13.

Fig. 13.—Coupling circuits for electro-magnetic cutting-heads, with equalisation inserted between output circuit and head. Fig. 13a is simple direct connection, with high resistance (500 to 5,000 ohms) heads. R=2 to 3 times cutting head load impedance. Fig. 13b shows single compensating network, with 15 ohm head; R=10 ohms; C=0.5 μF. Fig. 13c shows connections for variable compensation. R=2.5 ohms per section, and C=0.25 μF. per section. Changing the resistance changes the sensitivity, and varying the capacity alters the high-frequency response. Changing the resistance alone does not affect the frequency response appreciably, so long as the total series resistance is not less than half the cutting-head impedance (Ref. 17).

DECIBEL TABLE

Voltage Ratio (Equal Impedance)	Power Ratio	← − db + →	Voltage Ratio (Equal Impedance)	Power Ratio
1.000	1.000	0	1.000	1.000
0.989	0.977	0.1	1.012	1.023
0.977	0.955	0.2	1.023	1.047
0.966	0.933	0.3	1.035	1.072
0.955	0.912	0.4	1.047	1.096
0.944	0.891	0.5	1.059	1.122
0.933	0.871	0.6	1.072	1.148
0.923	0.851	0.7	1.084	1.175
0.912	0.832	0.8	1.096	1.202
0.902	0.813	0.9	1.109	1.230
0.891	0.794	1.0	1.122	1.259
0.841	0.708	1.5	1.189	1.413
0.794	0.631	2.0	1.259	1.585
0.750	0.562	2.5	1.334	1.778
0.708	0.501	3.0	1.413	1.995
0.668	0.447	3.5	1.496	2.239
0.631	0.398	4.0	1.585	2.512
0.596	0.355	4.5	1.679	2.818
0.562	0.316	5.0	1.778	3.162
0.531	0.282	5.5	1.884	3.548
0.501	0.251	6.0	1.995	3.981
0.473	0.224	6.5	2.113	4.467
0.447	0.200	7.0	2.239	5.012
0.422	0.178	7.5	2.371	5.623
0.398	0.159	8.0	2.512	6.310
0.376	0.141	8.5	2.661	7.079
0.355	0.126	9.0	2.818	7.943
0.335	0.112	9.5	2.985	8.913
0.316	0.100	10	3.162	10.00
0.282	0.0794	11	3.55	12.6
0.251	0.0631	12	3.98	15.9
0.224	0.0501	13	4.47	20.0
0.200	0.0398	14	5.01	25.1
0.178	0.0316	15	5.62	31.6
0.159	0.0251	16	6.31	39.8
0.141	0.0200	17	7.08	50.1
0.126	0.0159	18	7.94	63.1
0.112	0.0126	19	8.91	79.4
0.100	0.0100	20	10.00	100.0
3.16×10^{-2}	10^{-3}	30	3.16×10	10^{3}
10^{-2}	10^{-4}	40	10^{2}	10^{4}
3.16×10^{-3}	10^{-5}	50	3.16×10^{2}	10^{5}
10^{-3}	10^{-6}	60	10^{3}	10^{6}
3.16×10^{-4}	10^{-7}	70	3.16×10^{3}	10^{7}
10^{-4}	10^{-8}	80	10^{4}	10^{8}
3.16×10^{-5}	10^{-9}	90	3.16×10^{4}	10^{9}
10^{-5}	10^{-10}	100	10^{5}	10^{10}
3.16×10^{-6}	10^{-11}	110	3.16×10^{5}	10^{11}
10^{-6}	10^{-12}	120	10^{6}	10^{12}

To convert:

Decibels to Nepers, multiply by 0.115129.
Nepers to Decibels, multiply by 8.68591.

The decibel is one-tenth of the Bel, and is the unit of power-level difference, i.e., a measure of gain or loss (attenuation). The number of decibels corresponding to a given power-ratio is 10 times the common logarithm of that ratio.

$$N\ (\text{db}) = 10\ \log_{10} \frac{P_2}{P_1}$$

where P_1 = input power
P_2 = output power
$\frac{P_2}{P_1}$ = power ratio.

If the ratio is greater than 1 (unity), there is a power gain; if the ratio is less than unity there is a power loss. In the latter case it is usual to invert the fraction and express the answer so obtained as a power loss. The decibel can also be used to express the ratio between voltages and currents, but in such calculations it is implied that the impedances and power factors of the circuits, with which the respective voltages and currents are associated, are identical.

$$N = 20\ \text{Log}_{10} \frac{E_2}{E_1} \qquad N = 20\ \text{Log}_{10} \frac{I_2}{I_1}$$

Power-levels may also be expressed as the number of decibels by which they differ from an arbitrary reference known as zero power-level, which, in America, is usually 0.006 watts, or 6 milliwatts, and in Europe is 0.001 watts, or 1 milliwatt. Thus, a gain is stated as " up " or " plus db," and a loss as " down " or minus db." The decibel is also used to express difference in level in acoustics. In this case the arbitrary zero acoustic pressure level is generally taken as 1 dyne/cm^2, and the velocity level as 1 cm/sec. The *phon* is the unit of the objective loudness or sound level scale; the loudness of sound in phons is numerically equal to the sound intensity in decibels of an equally loud 1,000 c/s. pure tone.

Fig. 14.—Recommended design and constructional details of wooden studio recording console, which provides a complete recording apparatus, containing all necessary equipment for two turntable recording, with blanks and accessories storage, housed in one compact unit. Skeleton of the assembly is made from two 8ft. by 3ft. pieces of ¾in. plywood, halved, and then cut to dimensions shown. The top piece, which mounts on the four pieces of plywood, is 1in. by 12in. and is 5ft. long. The remainder of the assembly is held together with two lengths of 2in. by 2in. quartering for the part that will hold the turntables in position, and pieces of 2in. by 4in. quartering placed within the two outer compartments to hold the heavy casters. (Ref. 147).

DISC RECORDING CONSOLE.

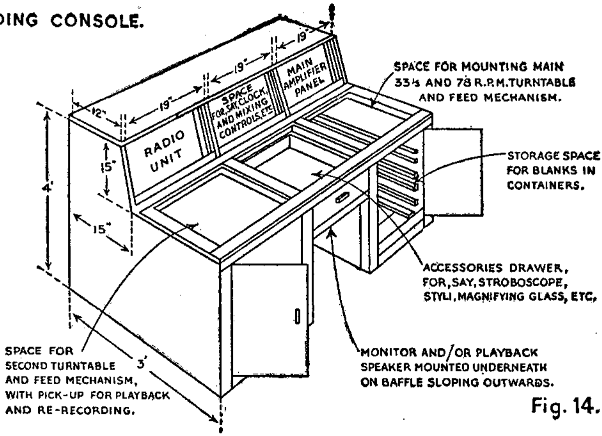


Fig. 14.

Fig. 15a.—Simple equaliser circuit for bass-boosting of constant-velocity electro-magnetic pick-up, when reproducing linear characteristic recordings. R and R_1 equal to half stated pick-up load impedance; R_2 adjust experimentally to give desired high-frequency residual response; for C choose value to have reactance equal to one-tenth stated pick-up load impedance at cross-over frequency. Fig. 15b shows treble boosting crystal pick-up equaliser and coupling circuit of type supplied by manufacturers to match overall response curves to particular applications, e.g., for reproducing constant velocity recordings (commercial pressings, etc.), C=0.001 to 0.05 μF; R_1= 0.1 to 2 megohm; R=0.5 megohm. Fig. 15c is bass boosting equaliser and coupling circuit for crystal pick-up. By adding parallel

*EQUALISER CIRCUITS

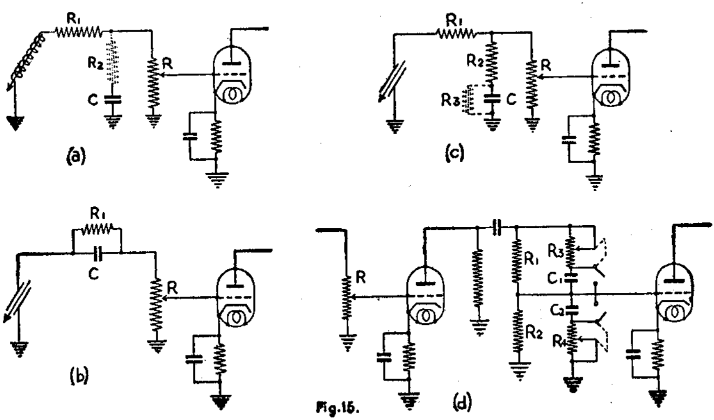


Fig. 15.

resistance across C (R_3), degree of attenuation may be controlled. Frequency where attenuation begins is determined by values of R_1, R_2, and C. For 6 db. per octave compensation: $C=0.01\ \mu F$; $R=1.0$ megohm; $R_1=0.5$ megohm; $R_2=50{,}000$ ohms; $R_3=0.1$ to 0.5 megohm. For 3 db. per octave compensation: $C=0.005\ \mu F$; $R=1$ megohm; $R_1=0.35$ megohm; $R_2=0.15$ megohm; $R_3=0.1$ to 2.0 megohm. For correcting constant amplitude response error of typical commercial crystal pick-up: $C=0.002\ \mu F$; $R=1.0$ megohm; $R_1=50{,}000$ ohms; $R_2=0.1$ megohm; $R_3=0.5$ to 2.0 megohm. Fig. 15d shows inter-stage amplifier equaliser circuit for bass or treble attenuation, for use with either magnetic or crystal pick-ups (Figs. 26a of 26c input circuits). R_3 and C_1 comprise treble boost circuit; R_4 and C_2 bass boost. Integral on-off switches on each potentiometer short out capacity when full resistance is in circuit, for "off" or normal response condition. Input valve is a triode, e.g., 6J5 or 6C5, with 50,000 to 100,000 ohm anode load. R_1 and $R_2=0.1$ megohm; R_3 and $R_4=50{,}000$ ohms; C_1 and $C_2=0.002$ to $0.02\ \mu F$ (depending on desired cross-over frequency). (Ref. 17).

FREQUENCY RANGES OF VARIOUS SOUND SOURCES.

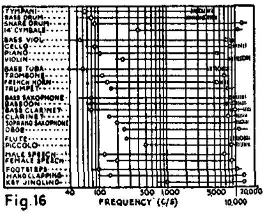


Fig.16

MEASURING OVERALL RESPONSE CURVE.

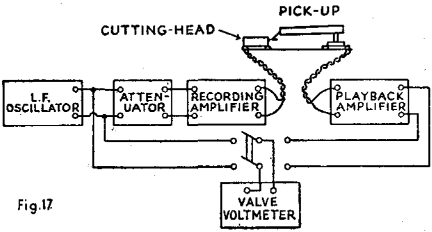


Fig.17

Fig. 16.—Frequency range of various sources of sound. Heavy lines = actual frequency range. Short vertical lines = ranges containing associated noises, such as key-clicks, buzzing of reeds, lip-noises, and hissing of air. Small circles indicate cut-off frequencies detectable in 80 per cent. of tests.

Fig. 17.—Connections of apparatus for measuring overall response curve, which includes the cutting-head, and in addition the pick-up and reproducing amplifier, but without cutting a blank. The head is removed from the feed mechanism and mounted upside down on three rubber supports. A cutting-stylus is inserted in the chuck, flat side upwards, and a spot of glue placed on the flat and allowed to harden. Care should be taken to ensure that the pick-up head and cutting-head are both on a common axis, otherwise chatter will occur between the needle and stylus, in spite of the glue. It will be seen that transverse vibration of the stylus will cause a corresponding movement of the needle tip in just the same way as a moving record groove effects it, and the pick-up will, therefore, generate a voltage that can be amplified and measured.

The test oscillator is then connected, through an attenuator calibrated in decibels, to the input of the recording amplifier feeding the head, and the pick-up connected with its appropriate shunt to the play-back amplifier. A valve voltmeter is arranged so that it can be switched across either the oscillator input or the pick-up amplifier output. This voltmeter need not be calibrated. Readings are then taken at various frequencies by setting the oscillator voltage at a suitable level by the voltmeter, and then switching the voltmeter over to the pick-up output and adjusting the input attenuator until the same reading is obtained. The gain or loss in decibels above or below a mean reference level is then read off from the position of the attenuator. (Ref. 33).

*MICROPHONE POSITIONS.

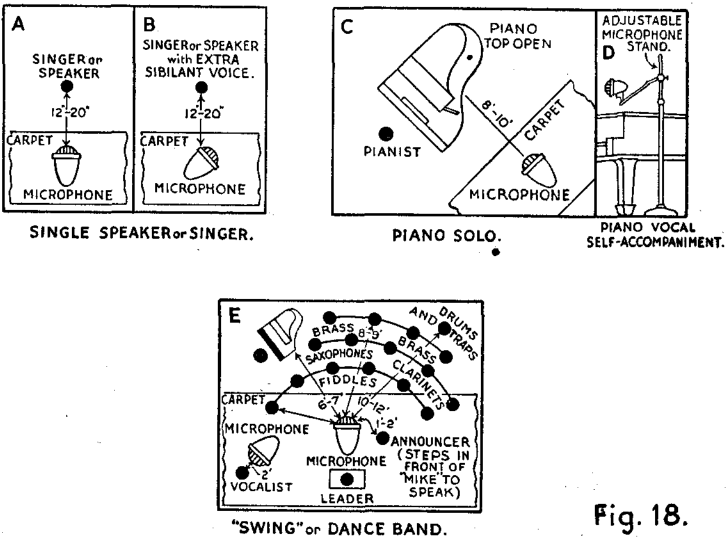


Fig. 18.

Fig. 18.—Normally correct placing of microphone(s), under specific conditions, for certain performers and musical combinations. (d) shows set-up for piano-vocal self-accompaniment, when music is played down under the vocal passages. The microphone should be 12 to 20 in. from the performer, and must not, for any set-up, be placed on the piano. Unusual recording enclosure acoustics make empirical methods, i.e., adding or removing acoustic treatment in the form of persons, clothes, curtains, mats, etc., changing the artistes' positions for better balance, followed by the making and playing of test cuts, desirable to determine the best microphone location. (Ref. 202).

*MICROPHONE PRE-AMPLIFIER.

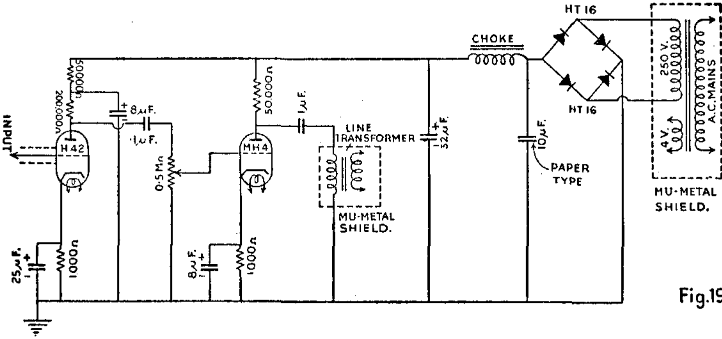
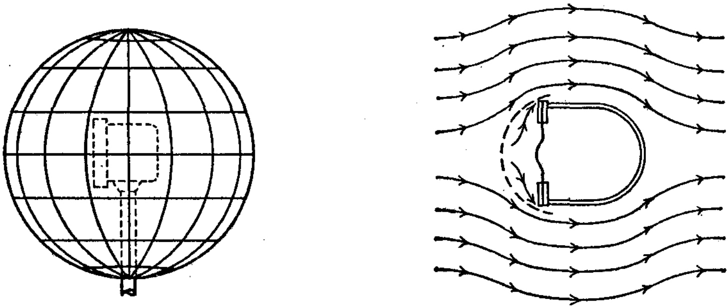


Fig.19.

Fig. 19. — Mains-operated pre-amplifier, suitable for ribbon microphone.

MICROPHONE WINDSCREENS.



(a) Fig. 20. (b)

Fig. 20.—To reduce wind excitation of microphones in outdoor recording, various types of wing-gag are used. The usual screen, consisting of a wire frame covered with very sheer silk, is shown in (a) and the shielding properties increase with the volume of the spherical screen. The Bernoulli type wind-screen (b) reduces the wind response about 12 db. (Ref. 183).

Fig. 21a.—Simple switching circuit for an electro-magnetic cutting-head. Speaker speech-coil impedance should match that of cutting-head. Fig. 21b is series circuit for simultaneous monitoring with a magnetic cutting-head. R is adjusted to produce comfortable speaker volume level. Output transformer secondary load is equal to the total impedance of the cutting-head in series with the parallel combination of the speech-coil and R. The amplifier should have ample reserve power to supply the speaker as well as the head. Fig. 21c shows series circuit with switching, for use when amplifier is used for recording/play-back. R_1 is adjusted for desired monitoring volume. R_2 may be one to three times cutting-head impedance, depending on amplifier power output. Fig. 21d is a

MONITORING CIRCUITS.

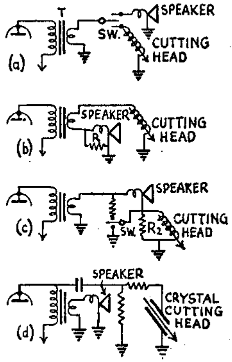


Fig.21.

OPTICAL RECORD TESTING SET-UP AND LIGHT PATTERNS.

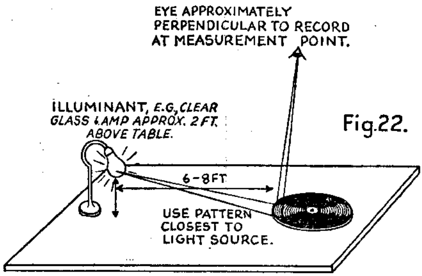


Fig.22.

simultaneous monitoring circuit for a crystal cutting-head, using speaker output-transformer primary for coupling choke. Shunt resistance may also be used to reduce speaker volume and stabilise loading. (Ref. 17).

Fig. 22.—Checking the frequency response and other characteristics, e.g., groove-wall smoothness as an index of surface-noise, etc., of a lateral recording by visual observation of the light diffraction pattern made by reflected light in the grooves, from a source that casts its rays obliquely across the record. (Also see Figs. 8-9, Buchmann-Meyer effect.)

Fig. 23.—Illustrates a typical example of the resulting pattern as seen by the eye. (Actually it is the characteristic of an electromagnetic cutting-head having no violent resonances, i.e., the profile of the band is smooth, with its maximum velocity/amplitude at 5,000 c/s.) The width of the light area of the pattern is proportional to the groove depth, or modulation amplitude, because the greater the ratio of modulated groove width to groove depth, the greater the band over which light is reflected. Thus, an exact quantitative measurement of the modulation amplitude (velocity/amplitude or lateral velocity, as it is variously called) can be obtained by measuring, with a pair of dividers or a ruler, the width of this band at right angles to the radial axis. (Also see Figs. 24, 32a.) An overall constant amplitude characteristic with flat frequency response will appear as a straight-side rectangle, and a modified constant velocity characteristic, with progressive high-frequency attenuation, will re-

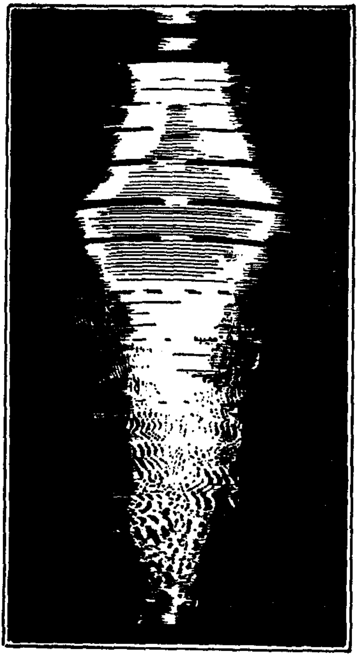


Fig. 23.

semble the shape of a Christmas tree or bell—hence the terms Christmas tree or bell patterns sometimes applied to this method. (Ref. 51.)

Fig. 24.—Illustrates standard procedure in making the frequency run for an optical test record, beginning (cutting inside-to-out), with a 1,000 c/s. reference frequency, and then recording successive tones, from a constant output audio-frequency oscillator, ranging from 30 to 50 c/s. up to 7,500 or 10,000 c/s., in a continuous band, terminating with another 1,000 c/s. reference cut. It is good practice to cut the 1,000 c/s. reference tone at its proper sequence in the actual run, using three levels, (a) the reference level, (b) 2 db. lower, and finally (c) 2 db. higher. (It is customary to record each tone for 10 seconds with 5 second intervals between frequencies.) Measurement of the linear variation in pattern width at these points then provides data for a directly measured db. calibration. It is simpler, however, to measure the total width of each band and produce an overall curve, which will be in terms of voltage, and can, of course, be converted into db. by consulting the voltage scale on a db. chart. With this data as a basis, necessary equalisation can be applied to correct faults in the curve and provide any

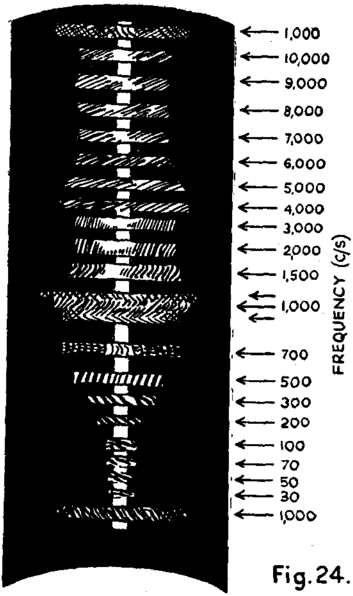


Fig. 24.

desired recording characteristic. An overall variation of not more than 5 db. from the ideal can be considered satisfactory. The width of the pattern in the unmodulated condition, i.e., no tone applied, is an index of amplifier residual noise, mainly hum. (Ref. 17.)

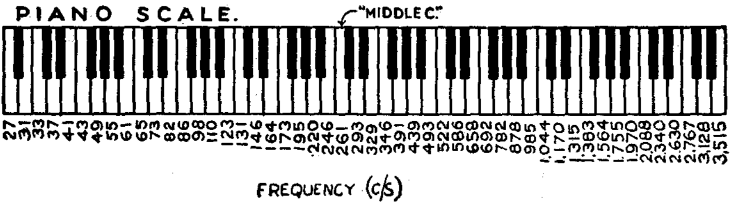


Fig. 25.

Fig. 25.—Piano scale showing the frequencies to which the keys are usually tuned, which is to a slightly different pitch from that used by physicists, based on Middle C = 256 c/s., and such scales are apt to be misleading. Frequencies of black keys can be obtained by multiplying the frequency of the white key below it by 1.059. This scale is useful for the approximate calibration of oscillators and rough determination of resonant frequencies, etc. (Ref. 190a).

*PICK-UP COUPLING CIRCUITS.

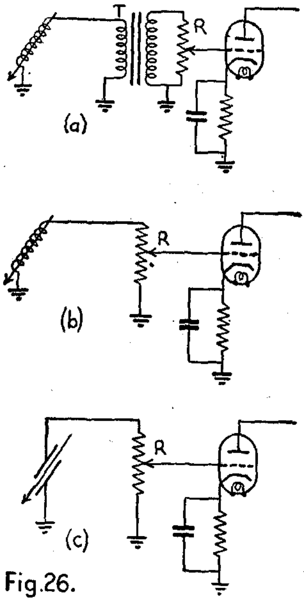


Fig.26.

Fig. 26a.—Step-up transformer coupling for low-impedance *magnetic pick-up (8 to 500 ohms). Transformer should be designed* to give maximum voltage step-up consistent with flat frequency response and minimum phase-shift over the required range. R is volume-control, 0.5 megohm. Fig. 26b shows direct coupling for high-resistance electro-magnetic pick-ups (2,000 to 20,000 ohms), **or** *for low-resistance pick-ups with* **high** *following-amplifier* **gain.**

*PICK-UP TRACKING ERROR AND OFFSETTING.

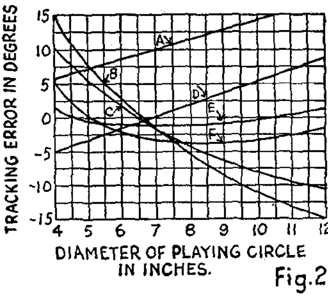


Fig.27.

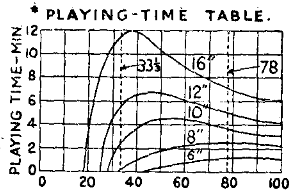


Fig.28.

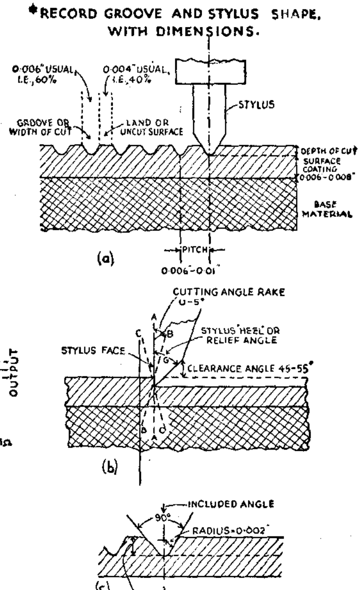


Fig.30.

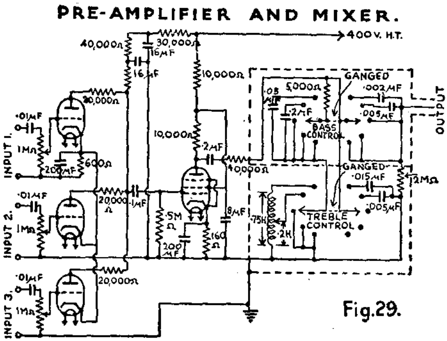


Fig.29.

R = stated load impedance of pick-ups. Fig. 26c is simplest coupling circuit for crystal pick-up. R is equal to load resistance specified by manufacturer for linear (constant amplitude) response, usually 0.5 megohm. (Ref. 17.)

Fig. 27.—Graphical representation of tracking characteristics of various pick-up carrying-arms, showing tracking error in degrees for various recording diameters. Curves A, B and C relate to straight arms. Curve A shows error for 10 in. arm. Curves B and C show error for 8 and 12 in. arms respectively, when needle is aligned to track correctly near centre of record. These curves indicate advantage of long pick-up arm. Curves D, E and F are based on a 10 in. arm with head offset at angles of 10, 23 and 30 degrees respectively. Optimum offset angle is shown to be 23 degrees with error equal to zero at two points and maximum error about 2 degrees. (Ref. 17.) Another method of reducing the tracking error is by the use of a needle inclined to the side, i.e., the so-called needle-tilting, the vertical angle of which changes as it progresses across the record. (Ref. 123.)

Fig. 28.—Chart shows useful playing-time for standard record sizes at various groove speeds. Small diameters (up to 10 in.) give longest playing-time at 78 r.p.m.; large records at 33⅓ r.p.m. Figures above are based on 96 grooves per inch and minimum diameter required for sine-wave reproduction at 8,000 c/s. With closer groove-spacing and/or smaller minimum recording, playing-time can be extended 25 per cent. (Ref. 17.)

Fig. 29.—Complete circuit of 3-valve (MH4's) electronic mixing stage, followed by pentode tone-corrector valve (TSP4). By various combinations of treble and bass switches, 25 different frequency response curves can be obtained. (Ref. 5.) Recommended for use in conjunction with main amplifier shown in Fig. 5.

Fig. 30.—Radial section of direct recording blank, showing (a) correct groove formation, (b) stylus cutting angle, and (c) stylus tip shape, with all dimensions. The cutting angle rake of from 0 to 5 degrees, usually negative, can be checked by aligning the face of the stylus (not the cutting-head necessarily) and its reflection in a smooth blank, when, of course, the two form a straight line, if the stylus is exactly vertical.

RECORD GROOVES (VERTICAL CUT).

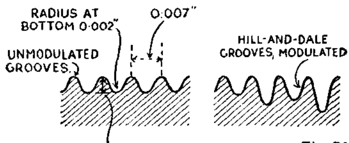


Fig.31.

Fig. 31.—Illustrates hill-and-dale cut grooves. It can be seen that the groove-wall width can be made very small as it does not have to withstand any lateral pressure, thereby permitting 150 to 200 grooves per inch.

*** RECORDING FREQUENCY RESPONSE CURVES.**

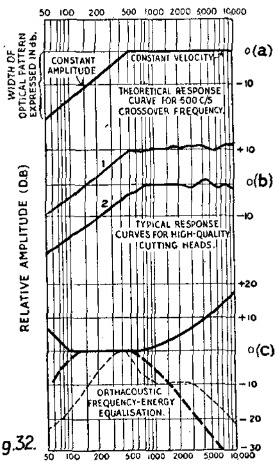


Fig.32.

Fig. 32a.—Modified constant-velocity curve used in standard commercial (solid-stock) recording practice. Below a certain frequency, known as the cross-over point (which may be any frequency between 250 to 1,000 c/s., with around 500 c/s. as average), recording is constant amplitude to limit low-frequency groove amplitude. Fig. 32b shows how actual electro-magnetic cutting-heads approximate the modified constant velocity curve seen in Fig. 32a. (1) is designed for 500 c/s. cross-over frequency; (2) for 1,000 c/s. Standard practice allows 2 db. overall variation from true curve, with 1.5 db. tolerance at cross-over point, for high-quality recordings. In Fig. 32c solid line indicates ideal amplifier characteristic for so called "Orthacoustic" recording system, in which the recorded level of part of the low-frequency range and all frequencies above the cross-over point is increased. This technique is based upon the frequency-energy analysis of speech and music, and this method of pre-emphasis and compensation in reproduction makes possible a reduction in noise-level. Dashed line shows peak energy per increment of frequency for human speech (average of male and female voices), and dotted line shows typical energy spectrum for orchestral music.

RECORDING LAY-OUT AND CONNECTIONS.

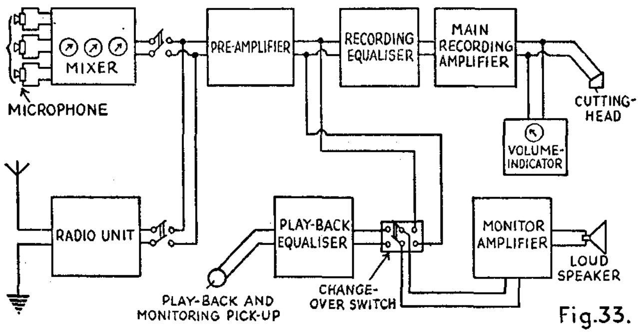


Fig.33.

Fig. 33.—Recommended lay-out and connections for complete disc recording unit. The advantages of the scheme are, among

SPEECH AND MUSIC FREQUENCY AND VOLUME RANGES.

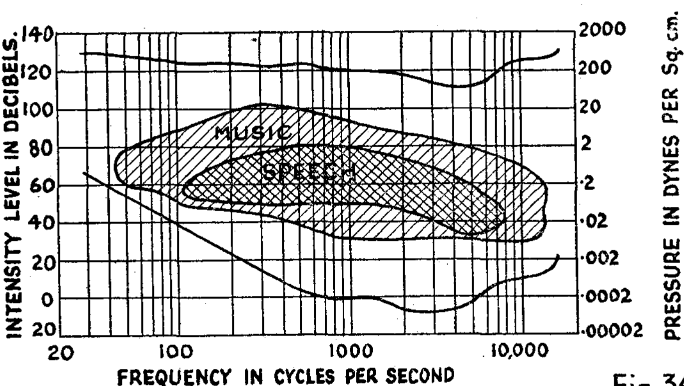


Fig.34.

others, that it permits play-back monitoring, i.e., the pick-up is placed on the record a few grooves behind the cutting-head, so that one can detect distortion, surface-noise, etc., during the actual cutting, and it enables a direct check to be made on the incoming quality and also, by flicking the change-over switch, to make an instantaneous comparison with the sound quality as recorded and then reproduced via the same monitoring equipment. (Ref. 31).

Fig. 34.—Frequency and volume ranges of speech and music. The reproduction of speech with perfect fidelity requires a 100 to 8,000 c/s. frequency range and a volume range of 40 db. Orchestral music reproduction with perfect fidelity requires a frequency range of from 40 to 14,000 c/s. at least, and a volume range of 70 db. The average maximum frequency range of lateral cut disc readings is 50—8,000 c/s., with a volume range of 25—40 db.

* STROBOSCOPE TABLE.

FREQUENCY of Supply (c/s.)		15	25	33	40	50	60	80	90	100
RECORD SPEED	78 r.p.m.	23	38	51	62	77	92	123	139	154

Fig.35.

Fig. 35.—To find the number of black spokes required for any speed and a.c. mains-frequency, the formula is:

$$N \ldots = \frac{120.f}{r}$$

where N = number of black spokes.
f = mains supply frequency.
r = speed of record required.

N.B.—180 black spokes are required at $33\frac{1}{3}$ r.p.m. for 50 c/s. mains.

*STYLI TABLE

STYLUS TYPE	USEFUL RECORDING LIFE	DISPOSITION AFTER USEFUL LIFE
Steel.	15 to 30 minutes.	Discarded.
Steel Alloy.	1 hour upwards.	Sometimes Re-ground.
Stellite, i.e., cobalt-chromium - tungsten alloy.	2 hours upwards	Re-ground.
Sapphire (synthetic).	6 hours upwards.	Re-ground.
Sapphire (natural stone).	10 hours upwards.	Re-ground.

Fig. 36a.—Dual neon-lamp flashers, which should be of the 0.5 or 1 watt type. R_1 and R_2 are 50,000 ohm potentiometers. The variable resistors are employed to set the peak potential re-

* VOLUME INDICATORS.

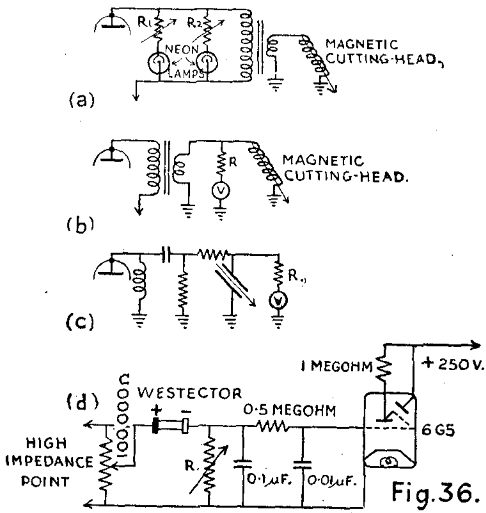


Fig. 36.

quired for ignition at the desired point. One or two lamps may be used; with the dual arrangement one lamp is set to flash when the amplitude exceeds the safe maximum, while the other is ignited whenever the modulation reaches the minimum required for satisfactory signal/noise ratio. The "low" lamp may be painted green or white and the "high" lamp red, and the method in operation is to maintain the amplitude such that the green lamp flashes constantly and the red lamp only intermittently, if at all.

Fig. 36b.—Output-meter type V.I., reading voltage directly at the cutting-head. "V" may be either a copper-oxide or valve voltmeter (r.m.s. type), calibrated in db. if desired. R is multiplier required to establish maximum range (if required). Typical scale ranges suitable for various cutting-head impedances are:

4 ohms = 2.5 volts.
8 „ = 4 „
15 „ = 5 „
500 „ = 30 „
5,000 „ = 100 „

Fig. 36c.—High-range a.c. voltmeter used as V.I. for crystal cutting-head. R is the multiplier (150,000 ohms for a 1 mA. copper-oxide milliameter and 150 volt scale. (Ref. 17.)

Fig. 36d.—"Magic Eye" tube as average and/or peak V.I. When R is large, say 1 Meg., condenser C charges up to peak volts, and then leaks away slowly; when R is smaller, say 50,000 to 100,000 ohms, the leakage is greater and the indicator follows "average" level. If desired, two values of R can be inserted by means of a switch. About 50 volts input is needed to work "Magic Eye" (which is fairly logarithmic in action), hence high impedance input. Westector is 36 volt type.

BLANKS TABLE.

Base	Type Surface Coating	Processing	Commercial Brand of Blanks of Types Listed	Suggested Method of Manufacture for Amateur Recordists
Aluminium alloy; tin; zinc, and pewter.	None.	Before cutting, a lubricant may be applied, e.g., thin oil or vaseline.		
Aluminium alloy; zinc; glass; bakelite and cardboard.	Cellulose esters with plasticiser; includes: blanks, termed "cellulose acetate" and nitro-cellulose.	Chemical treatment, e.g., applying acetic acid after cutting, generally optional.	M.S.S. - Watts; E.M.I.; R.C.A.; Piodisc; Presto; etc.	(1) Cover a metal or glass disc of required size with benzyl cellulose (from a solution) to a thickness of 0.006 to 0.008 in. (2) High-grade cellulose thinners is applied liberally, in a dust-free atmosphere, to the surface of the used blanks and, after a time, the old grooves will collapse and, if left for about 24 hours, a new surface is produced. Results with this method depend on freedom from dust and evenness of application. (3) Pour quantity of amyl acetate, with a "pea" of camphor to each 4 oz., on the blank rotating at about 10 r.p.m. and then efface the old grooves by radial movements with a 1 in. camel-hair brush. Leave blank on turntable or place on level elsewhere to allow gravity and surface tension to act in producing a new surface. (Ref. 156)
Aluminium alloy; zinc; or other metal.	Thermo - setting phenolic resin, with plasticiser.	Heat treatment, i.e., the surface is fairly soft and "uncured," and a baking operation in an oven hardens it after cutting.		Try brushing or spraying synthetic resin lacquers of the phenol or amino type (0.006 in. thickness) on suitable disc bases. Or apply glyptal or alkyd resin in a suitable solvent, to plain aluminium or zinc bases, rotating at about 5 r.p.m. in a horizontal plane. Continue rotation, in a dust-free atmosphere, until layer has air-dried, and will no longer "run" and is "tack-free." The grooves can then be cut in layer and subsequently hardened by baking. (Ref. 156).
Aluminium alloy; zinc; bakelite; glass, and cardboard.	Gelatine and gelatinous compositions.	Chemical treatment, i.e., hardened and polished by fluids, containing formaldehyde (or dichromate solution) and waxy oils respectively.	Simplat	To remove existing coatings leave in following bath at 37 degrees C. for 10 hours or more: Pepsin, 1 gram; Hydrochloric acid, 5 c.c.; Water, 1,000 c.c. For re-coating process see Brit. Patent No. 438,029 (1935) and Ref. 156.
Unbacked, i.e., flexible.	Cellulose derivatives or gelatinous compositions.	Harden by formaldehyde application.		Try cellulose sheeting, of different types, cut to size.

*DIRECT DISC RECORDING DEFECTS TABLE

DESCRIPTIVE TERM	SYMPTOMS (Visible and/or Audible)	CAUSES AND CURES
Banding (or Defective Tracking).	Uneven groove-spacing.	Faulty action of traversing mechanism, e.g., binding. Also may be due to lack of precision in feed gear or lead screw in cheap equipment.
Chatter.	An erratic "spotted" pattern in grooves, with short alternate light and dark strips.	Poor stylus or one set at a wrong angle; or by insufficient vertical damping. Too deep a cut in thin disc coating may also produce a similar effect, which is most likely to occur close to centre of record.
Cut-over (or overcutting; Groove-wall breakdown; Cross-over.	One groove running into the next, causing "repeating."	Overmodulation, i.e., too high recording level, for particular groove-pitch in use, or cutting too deep.
Cutting-through.	Penetrating through coating of disc and into base material, usually thereby damaging stylus.	Cutting too deeply; extraneous vibration; damaged gear tooth in feed mechanism; dirt on lead screw; feed mechanism not fully engaged when cutting-head lowered on record surface, and later slipping into engagement with a jar; hard drop in setting down cutting-head; cutting-head bouncing after thread-tangle; failure to raise cutting-head as end of feed mechanism reached.
Dry-cut.	A bad groove-cut, indicated by the thread appearing kinky, brittle, and dry.	Incorrect cutting-angle; bad stylus; old or inferior quality blank.
Echo (or Pre-echo, "Ghost" effect, Double-Talk).	The modulation from one groove is impressed faintly on the adjacent groove.	Overmodulation; too deep cut; too light pick-up; use of blunt non-ferrous play-back needles; soft type of blank coating; and, with solid-stock pressings, displacement of grooves during processing, or surface flow of matrices in pressing operation; or surface flow of original wax during cutting.
Flutter.	A type of "wow" having fluctuation changes between 6 to 30 per second. Produces harmonic distortion in lateral groove, and increases residual noise-level by modulating surface-hiss.	Undesired vertical oscillations of cutting-head caused by mechanical resonance, e g., the mass of the cutting-head in combination with blank coating material. Remedy by adding vertical damping, say, oil-dashpot type. Also due to irregular blank surface, non-level or unbalanced turntable; or transmission of motor vibration through turntable drive or suspension; poor play-back equipment; can also be caused by magnetic pull of cutting-head on steel turntable beneath—use ¼ in. thick beaverboard or lino disc between turntable and blank.
Grey Cut.	Reflected light reveals that record grooves have dull greyish appearance. Results in increased surface-noise.	Imperfect or worn cutting-stylus; incorrect cutting-angle.
Groove-jumping.	Pick-up needle will not remain in groove on play-back.	Too shallow cut; uneven play-back turntable; pick-up carrying-arm stiff or out of alignment; unsuitable needles.

DESCRIPTIVE TERM	SYMPTOMS (Visible and/or Audible)	CAUSES AND CURES
Groove-skating.	Pick-up needle tending to climb or "skate" the groove walls, causing fluctuations in output, with accompanying several db. rise in surface-noise, in addition to increased harmonic distortion and record wear.	Usually pick-up with too low vertical pressure, particularly if combined with appreciable tracking error and horizontal inertia. Also caused by cutting with broken-tipped sapphire. (A minimum force of 12 grams is required to prevent "skating" with the 0.002 in max. amplitude and 90 degree groove commonly employed.)
Hum.	Small arrow-head (Vs) patterns, distributed over record surface.	May be due to excessive hum in recording amplifier. Often occurs with cheap recorder, where hum is masked in play-back by restricted low-frequency response.
Kinky Thread.	Thread breaks off into short loops or tends to curl tightly, instead of lying straight like a flexible chain.	Either dull, worn stylus or over-dry or aged blank.
Orange-Peel Effect.	Mottled appearance (similar to skin of orange) on blank surface that increases surface-noise.	This surface irregularity is usually attributable to manner of applying surface-coating, e.g., dipping.
Patterns (or Patterning; Pattern-weaving).	Generic term applied to peculiar designs that are sometimes visible on blanks examined, at a certain angle, under direct light.	Usually turntable vibration—vertical or lateral, or a combination of both. Check adjustment of rim-drive tension, with this type of turntable; and, on rubber mountings, adjust tightness of mounting bolts.
——Moire	A pattern (resembling the cloth of the same name) or "watered-silk" effect.	Usually indicates vibration in turntable mounting or transmitted to it by motor-drive coupling; or worn rubber-drive wheels; thread or dirt in feed mechanism; overloaded motor; amplifier hum.
——"Skip."	Cutting-head has "skipped" portion of blank surface (on one radius), due to "bouncing" during recording.	Produced by dented or bent base of blank, or swirled coating. Occasionally due to hard spot in coating. Use advance ball.
——Spoke	Recurrent design in the form of curving spokes, i.e., alternate light and dark areas, or arrow-heads (Vs).	Light and heavy cutting, due to motor-drive vibration, or worn pulley or bearings; or impulses from an overloaded motor
Piano-Whine.	Unpleasant whine when reproducing pianoforte recording.	Sudden variations in recording and/or reproducing turntable speed, due to large amplitudes occurring in piano music. Use heavier turntable.
Rumble.	Undesired low-frequency noise present in disc play-back.	Vibration; sometimes due to external noises, e.g., traffic or movement of people. Especially noticeable when too much bass boost in reproduction is being used. Remedies are to (a) record more bass, (b) oil turntable shaft with thick motor oil.

DESCRIPTIVE TERM	SYMPTOMS (Visible and/or Audible)	CAUSES AND CURES
Surface-Noise (or Scratch; Background Noise).	Hissing noise in disc reproduction.	Dust and foreign particles in grooves; aged blank or type of blank used; worn cutting-stylus; wrong depth of cut, usually too deep; incorrect stylus "rake" angle; stylus not straight in cutting-head; cutting-head not tracking across a radius (approx.) of blank; type of pick-up and needle used. In solid-stock pressings noise is due to their granular structure, steps in processing, and embraces all frequences. (Ref. 113.)
Swirl Lines.	Curving areas of extra thick coating radiating from centre of certain blanks.	Often present in blanks coated by "dipping"; sometimes causes "skip" patterns.
Thread Tangle.	The coating thread during cutting becomes tangled at the stylus, and if pulled to release or allowed to remain, can cause cutting-through or uneven groove spacing; also responsible for crackling noises in play-back.	Usually due to removed coating thread coming around stylus on outside, i.e., side nearer to outer edge of blank, instead of around inside. Correct by slight biassing (not more than 5 degrees) of stylus cutting-face; use of brush or other means of thread control; or cut inside-out.
Twinning (or Twin-grooving).	Irregular groove-spacing, making width of walls or "lands" uneven (generally in pairs, i.e., "land" is alternately wide and narrow).	Faulty action, e.g., binding, of traversing (feed) mechanism, or of drive to this mechanism.
Whine.	Fluctuation in apparent loudness and frequency of a reproduced sound. A type of "wow."	Speed of recording and/or reproducing turntable varying at a slow rate.
Whistling (or Squeaking).	Whistling noise of any kind heard during cutting; usually occurs in conjunction with dull cut and dry, crumbly thread.	Denotes a bad stylus, the wrong cutting-angle, or both. Occasionally due to aged blank coating.
Wows (or Wow-Wows).	Rhythmic or arrhythmic change in intensity (up to 6 per second) in reproduced sounds.	Fundamentally arises from speed fluctuation in either recording or reproducing equipment, but made more apparent by phenomena of stationary waves in an enclosure. If of regular period identifiable with turntable rotation speed, it is probably connected with turntable drive system, e.g., slippage due to flat pulley, or oil on pulley (in rim-pulley drives); loose set screw; worn gear section. Also produced by blank slippage where no centre clamp used; oversize centre-hole; warped blank; warped or out-of-round turntable. Occasionally, binding or non-aligned bearings in feed mechanism.
——Gargle.	Speed variation 30 to 200 c/s.	
——Whiskers.	Speed variation over 200 c/s. (As a rule not visible in the form of patterns, unless associated with vertical vibration. Stroboscope may reveal certain types of "wow" by appearing to oscillate. Aurally disturbing.)	
——Waver (or Wobble).	Intermittent fluctuation.	Worn turntable bearings or insufficient tension on drive or idler-pulleys.

SELECTED REFERENCES

Most of the comprehensive list of articles on disc recording and cognate topics given below can be perused in The Patent Office Library, 25, Southampton Buildings, Chancery Lane, London, W.C.2, which will also supply photostatic copies of those articles available. Photostatic copies may also be obtained from the Library of Congress, Washington, D.C., or from the New York Public Library, New York, U.S.A. Current issues of **The Wireless Engineer**, and **Science Abstracts**, as well as the publications listed below, should be consulted for useful up-to-date abstracts and articles on disc recording.

C. = **Communications** (American).

E. = **Electronics** (American).

E.T.S.W. = **Electronics and Television and Short-Wave World.**

J.A.S.A. = **Journal Acoustical Society of America.**

Journal I.E.E. = **Journal Institution of Electrical Engineers.**

J.S.M.P.E. = **Journal Society of Motion Picture Engineers** (American).

Proc. I.R.E. = **Proceedings Institute of Radio Engineers** (American).

Trans. Amer. I.E.E. = **Transactions American Institute of Electrical Engineers.**

W.W. = **Wireless World.**

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DISC RECORDING AND REPRODUCTION STANDARDS

The general absence of standards for electrical transcription, i.e., disc recording and reproduction for broadcasting, has resulted in the use of as many as ten equalising networks by some U.S.A. radio stations. The National Association of Broadcasters in America has co-ordinated the work of a special committee, consisting of representatives of all interested organisations, which has prepared a series of standards, the first sixteen of which have already been adopted and submitted to the industry.

The standards, complete to date, follow:

1. OUTSIDE DIAMETER.

OUTSIDE DIAMETER	PRESSINGS	LACQUER ORIGINALS
16in.	$15\,^5/_{16}$in. ± $^3/_{32}$in.	$17\frac{1}{4}$in. ± $^1/_{16}$in.
12in.	$11\frac{7}{8}$in ± $^1/_{32}$in.	$13\frac{1}{4}$in. ± $^1/_{16}$in.
10in.	$9\frac{7}{8}$in. ± $^1/_{32}$in.	$11\frac{1}{4}$in. minimum

2. CENTRE HOLE: 0.286in. with ± 0.001in.
3. TURNTABLE PIN: 0.2835in. within ± 0.0005in.
4. OUTERMOST GROOVE:
   16in. outside start $15\frac{1}{2}$in. within ± $^1/_{16}$in.
   16in. inside start $15\,^9/_{16}$in. maximum.
   12in. outside start $11\frac{1}{2}$in. within ±0.02in.
   10in. outside start $9\frac{1}{2}$in. within ±0.02in.
5. INNERMOST GROOVE: $33\frac{1}{3}$ r.p.m.—$7\frac{1}{2}$ in. minimum.
   78 r.p.m.—$3\frac{3}{4}$ in. minimum.
6. UNIFORMITY OF GROOVE SPACING: Pitch deviation shall not exceed 5 per cent. of main groove pitch.
7. STOPPING GROOVE: A locked concentric type should be used.

8. NUMBER OF BLANK GROOVES: Shall be not more than **4** and not less than **2**, excluding starting spiral.

9. RECORDING SPEEDS: Shall be 33$\frac{1}{3}$ or 78.26 r.p.m. within ±0.5 per cent.

10. WOW FACTOR: Maximum instantaneous variation from the mean speed of the *recording* turntable shall not exceed ±0.1 per cent. of the mean speed.

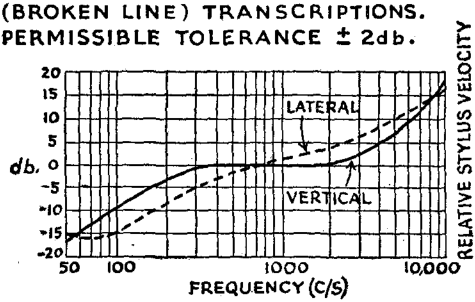
11. WARP: Maximum departure from true plane ± $^{1}/_{16}$*in.*

12. LABEL INFORMATION: Shall contain (as minimum) — (a) Lateral or Vertical cut, (b) Speed, (c) Outside-in or Inside-out restart, (d) Recording frequency characteristic.

13. FREQUENCY CHARACTERISTIC (Lateral): See accompanying Figure.

14. FREQUENCY CHARACTERISTIC (Vertical, i.e., Hill-and-Dale): See accompanying Figure.

RECORDING CHARACTERISTICS FOR VERTICAL (FULL LINE) AND LATERAL (BROKEN LINE) TRANSCRIPTIONS. PERMISSIBLE TOLERANCE ± 2db.



15. STARTING SPIRAL: 8 grooves per in. tolerance, ± 2 grooves per in, recommended as good engineering practice.

16. RECORDING GROOVES: 96, 104, 112, etc., in increments of 8. Tolerance ± 2 grooves per in.

17. RECORDED LEVEL: The programme level measured by the standard volume indicator shall be the same as the level required to record a 1,000 c/s. note at a velocity of 5 cm./sec. This allows for the 10 db. margin usually present between signal and reading of volume indicator. This standard contemplates peaks running as high as 15 cm./sec., which is the maximum velocity that can be traced without distortion in the inner radius of a 33$\frac{1}{3}$ r.p.m. record.

18. SIGNAL/NOISE RATIO: The noise level measured when reproducing a record over a frequency range of 500-8,000 c/s. shall be at least 36 db. below the level obtained under the same conditions when using a 1,000 c/s. note at 5 cm./sec. This measurement is intended to give a fixed reference level for measuring noise, and does not take into account programme level actually recorded or programme dynamic range. Pre-emphasis, i.e., equalisation, will improve the S/N ratio a further 8 db.

19. CENTRICITY OF HOLE IN DISC: The hole in the disc shall be concentric with the recording groove spiral to within 0.003 in.

20. TURNTABLE DIAMETER: Minimum diameter of the reproducing turntable shall be 15⅝ in.

21. TURNTABLE TORQUE: Minimum torque at the turntable shall be 100 in. ozs.

22. WOW FACTOR: Maximum instantaneous deviation from the mean speed of the *reproducing* turntable shall not exceed ±0.3 per cent. of the mean speed.

23. PICK-UP TRACKING ERROR: Maximum tracking error shall be 6 degrees at 4 in. diameter and 10 degrees at 15½ in. diameter.

24. PICK-UP WEIGHT: Maximum vertical force required by the pick-up shall be 1½ oz. (42 gm. approx.).

(N.B.—Standards 20 and 21 are fixed to allow for "slip-starting," i.e., putting record on running turntable.)

ADDITIONAL RECOMMENDATIONS: (a) The output level of pick-up equaliser combination shall be minus 65 V.U. for velocity of 5 cm./sec. at 1,000 c/s.; (b) Frequency response of pick-up, from a vinylite pressing, shall be the inverse of the N.A.B. recording characteristic within ± 2 db. For "home" use at 78 r.p.m. a network to reduce surface-noise above 4,000 c/s. is advised. (c) The pick-up shall be designed so that translation loss at 8,000 c/s. between inside and outside diameters of 16 in. vinylite tone record shall not exceed 6 db. (d) Turntable cabinet height should be 30½ in.

Owing to wartime conditions, standards of groove **contour**, distortion, low frequency noise, and standard tone records, are not yet published. In addition to the above standards, the committee recommend the adoption of a glossary of recording standards, which includes most of the terms peculiar to the subject, but this is not available at present.

GLOSSARY

ABRASIVE.—It is often stated that an abrasive **filler**, e.g., rottenstone, is incorporated in the shellac-base **solid-stock** formula for commercial **pressings** to grind the needle tip to the groove shape, on the principle that it is better for the record to wear the needle than for the latter to wear the record. But this is erroneous, as reputable manufacturers, in general, do not include abrasives in the stock for this purpose. But a hard pigment, e.g., barytes, which has a crystalline structure, used as a **filler**, is abrasive to an extent, and so a balance has to be struck between this factor and durability. The coating of direct discs should contain no abrasive substance, which omission, although reducing the resistance of the record to **wear**, also markedly lessens the surface-noise.

ACOUSTIC ABSORPTION.—When a sound wave meets an obstacle, e.g., the walls of an enclosure, some of the energy is transmitted, some reflected, and the balance is absorbed. The coefficient of absorption is defined, for a plane surface, as the fraction of incident energy that is not reflected, and it varies considerably with frequency. The total absorption determines the **reverberation period** in a given volume. (Ref. 183.)

ADVANCE BALL.—Small sapphire ball, or depth shoe, situated immediately in front of **stylus** and riding lightly on record material, is intended to smooth the way for the cutting **stylus** and maintain an even depth of cut. Unless equipment is designed for use with an advance ball, its incorporation is likely to cause trouble, e.g., thread fouling.

AMPLIFIER CONSTRUCTION.—All input circuits should be kept compact and thoroughly screened, with all leads made short, braided and earthed, particularly if amplifier is located near motor. Input volume controls, and **mixer** controls, if any, should be mounted in cans and the leads encased in braid. It is generally advisable to bring all input earth returns to a common point. **Equaliser** circuits are commonly responsible for hum troubles. Components and leads should be arranged for minimum hum pick-up and well screened. All metal parts in the equipment, e.g., turntable, motor frame, amplifier chassis, should be earthed. Good power supply regulation, filtering and decoupling are essential in the amplifier design, particularly if motor is connected to same a.c. line and the power supply regulation is poor.

AMPLITUDE.—The maximum height, or maximum depth, of a **waveform**, measured from its base line or middle position. Roughly, controlled by the **level** used in recording. The energy contained in a wave varies as the square of the amplitude of the wave.

APPLICATIONS.—The multifarious and growing applications of direct disc recording are covered in Ref. 202.

AUDITORY PERSPECTIVE.—The faculty of the human pair of ears to appreciate relative distances and bearings of sound sources in combination in an enclosure. Can be reproduced by means of a three-channel reproducing system. Also Localisation, Spatial Effect.

BAR.—Unit of alternating acoustic (sound or excess) pressure on a surface or in a freely progressing wave. Equals one r.m.s. dyne per sq. cm.

BINDER.—The basic material in **solid-stock pressing**, chiefly **shellac**, which causes the various substances to adhere together and form, after heating and cooling, a solid mass.

BLANK.—Strictly, refers to an unrecorded disc only. A good inexpensive blank is the chief obstacle preventing the wider use and application of direct recording, but present developments will undoubtedly solve this problem, when it is permissible for all the details to be released. For example, polyvinyl alcohol, dissolved in a suitable solvent, may make an excellent disc recording medium, and ethyl-cellulose sheeting (0.015 in.) is already being used for embossed long-playing records.

BUZZ.—In record reproduction is caused by imperfect or discontinuous contact of **play-back** needle in groove, due to high mechanical impedance, etc., referred to needle point. It is an audible effect of **tracing distortion.**

CELLULOSE ACETATE.—Acetylcellulose. The basic ingredient in some varnish formulæ originally used for **direct recording** disc coatings. The term is commonly used as a synonym for instantaneous or direct recording., as distinguished from records made by **processing**, but it is a misnomer because modern direct **play-back** discs do not have acetate coatings. **Pressings** are, however, made in this substance, instead of the usual **solid-stock** material.

CENTRE-FADING.—Falling-off in reproduced quality as centre of record is approached, due to inability of pick-up needle tip to follow waveform accurately. This loss of high frequencies is not cured by "top boosting," but by recording at a lower level . (Ref. 48). See Equalisation.

CONSTANT LINEAR VELOCITY RECORDING. — The basic principle of this system is that the linear speed at which the record **groove** passes under the recording/reproducing stylus is constant from start to finish. Obviously, to accomplish this it is necessary that the speed of rotation must be steadily increased towards the centre of the record. In reproduction, this can be effected by a variable gear or special governor attachment controlled by the movement of the pick-up carrying-arm. It is claimed for this method that, as the linear velocity at the outer radius of the normal constant angular velocity record is unnecessarily high, a playing-time of 18 mins., with a 12 in. record, is possible. Also known as Constant Groove Speed Recording, or Varying Angular Velocity Recording.

CONTINUOUS RECORDING.—A minimum of two **turntables** and associated equipment is required to make satisfactory disc recordings without a noticeable break in the recorded material. By recording with both turntables towards the end of one disc, just prior to the change-over, the slight overlap will preserve continuity.

CONTRAST EXPANSION. — A means for compensating for volume compression during recording or transmission of music that enables a wider range of sound intensity to be reproduced than otherwise would be possible. It would be a great advance if commercial recordings could have the coefficient of compression notated on the label. Thus, in reproduction, the play-back equipment would be set to an expansion coefficient equal to the compression coefficient, so that the ultimate rendition would have the same dynamic range as the original performance. (Refs. 125; 126.)

COPYRIGHT.—Certain points in copyright law, raised by the making, use and sale of direct recordings, transcriptions and commercial records, are dealt with, in England, by Phonographic Performance, Ltd., 144, Wigmore Street, London, W.1, and Performing Right Society, Ltd., 33, Margaret Street, London, W.1.

COUNTERWEIGHT. — A weight fitted on certain types of **cutting-head** and **pick-up** to reduce their pressure or weight on the **blank**.

CROSS MODULATION.—Sum-and-difference tones usually produced by non-linearity in some part(s) of the recording/**play-back** system. Such distortion is often attributed mainly to the amplifier and/or play-back needle, but as much as 12 per cent. cross-modulation can be realised if the burnishing ball on the cutting **stylus** tip is too large. Optimum value of ball size will reduce such distortion to 1 per cent. (Ref. 69.)

CROSS-OVER FREQUENCY.—The arbitrarily chosen frequency, between 250 and 1,000 c/s., in modified constant velocity recording, at which the change-over from constant amplitude to constant velocity cutting is made. Also known as the Transition Frequency, Change-over Frequency, or Turn-over Point.

CUEING.—The process of making starting points, or reference marks, on records to be used for **dubbing** or re-recording.

CUT.—To cut means to engrave a groove. The cut means the **groove.**

CUTTER.—Term sometimes applied to both the **cutting-head** and the **stylus.**

CUTTING-HEAD.—The recording process begins with the cutting-head, whose principal requirement is to engrave a mechanical facsimile of a given sound wave(s) into the recording material. To do this, the cutting-head should be independent of any load imposed by the cutting medium. Both electro-magnetic and piezo-electric crystal heads are currently used. (Refs. 9; 10; 17.)

DIG-IN ANGLE.—The setting of the cutting **stylus,** in relation to the blank surface, is such that the tip is driven into the coating; the opposite of drag-angle, i.e., the tip drags along the surface.

DIRECT RECORDING.—The method of sound recording on discs which, after little or no **processing,** play-back immediately. This latter feature is the fundamental difference between commercial gramophone recording and direct recording. Also known as Instantaneous or Spot Recording.

DISC.—Abbreviation for recording disc. Also spelt Disk. Alternative terms occasionally used, Plate, Platter. Schallplatte (German) and Disque (French) for gramophone record.

DRIVE HOLES.—Three holes spaced around the centre hole of a **blank** to engage a drive pin in the turntable, thereby preventing slippage during recording.

DUBBING.—Strictly, this term refers to adding sounds to an original record by re-recording it, and while this is being performed, mixing in other sounds, whether from a **microphone** or other recordings. As generally used the term means making a copy of a record by re-recording, i.e., the original record is reproduced with a **pick-up,** whose amplified output is fed to the recording amplifier. It must be remembered that surface-noise, peaks, etc., in the original record, unless equalised in **play-back,** will be additive in the final re-recording. Term is derived from the old "doubling," i.e., a mechanical duplicating process for the old wax cylinders.

DUBBING (STYLUS).—Means lapping with diamond dust.

EAR.—It must be remembered that the human ear, although subjective, is the final arbiter in questions concerning sound recording/reproducing quality, and response curves, measurements, etc., are not the ultimate criterion. But, of course, the term "ear" is the collective ear of several experienced artistic and technical judges.

EDISON, THOMAS ALVA (1847-1931).—Amer. inventor of the phonograph, which used the **hill-and-dale** cut on cylinders, and the original model (1877) was essentially a direct recorder. (Ref. 192.)

ELECTRICAL TRANSCRIPTION.—Disc recording, usually **slow-speed vertical cut** type, specially made for broadcasting. In U.S.A., if not a **direct** recording, it is generally a **vinyl acetate pressing.** (Ref. 149.)

ELECTRO-PLATING.—In **processing**, the deposition of a layer of copper on the original recording (or wax master), after the surface of the latter has been made conducting by brushing on graphite powder or by **sputtering.**

EMBOSSED RECORDING.—Recently revived in America, the embossing or burnishing method, in which no coating material removed, used in combination with **constant groove-speed recording,** makes possible 30 minutes' music recording or 45 minutes' speech recording on one side of a 12 in. disc. A polished, round, embossing **stylus** (in contrast to the usual sharp cutting or engraving tool), which is also used for play-back, impresses grooves in, e.g., a lacquer coating or in ethyl-cellulose, producing a high signal/noise ratio. (Ref. 25.)

EQUALISATION.—Can be defined as the logarithmic progressive increase in amplitude of the highest frequency that it is desired to record, from the outside to the inside of a record, and is especially desirable in slow-speed recording, to compensate for the falling-off in quality towards the centre of the record, due to decreased lineal velocity. The equalisation control can be operated manually, motor operated, or driven by the cutting-head traversing mechanism on the recorder. It must be remembered, when using equalising networks for any form of frequency correction, that the equaliser and **cutting-head** curves must match accurately enough to produce the desired effect, as incorrect equalisation will cause irregularities in the response curve, which are often more objectionable to the ear than lack of overall range. Alternative names: Tone Control or Tone Compensation. (Refs. 17; 31; 172; 205).

EXPENSE.—It is a fallacy to believe that good quality **direct recordings** can be made only with elaborate and very expensive apparatus. This does not mean that first-class records can be made with equipment constructed from Meccano parts, odd lengths of screwed brass rod, converted cheap pick-up, weak electric or spring motor, and fed from a super-heterodyne radio receiver, but it is a reminder that basically reliable equipment, perhaps obtained second-hand or damaged, can be made to produce excellent results, limited only by the operator's ingenuity and ability.

FEED MECHANISMS. — These are mechanisms for traversing the **cutting-head** slowly across the face of the **blank**, to produce the prescribed number of grooves per inch. There are several types of tracking mechanism, e.g., the swinging arm or fan type, including the underdrive tangent type, in which the cutting-head is attached to a follower arm driven by a long leadscrew geared to the turntable shaft (these have a tracking error); and the straight-across carriage types, with overhead feed (leadscrew driven by spindle through worm and gear or by belt from turntable spindle), or the undermounted type, with the cutting-head suspended from an extension arm carried on guide-rails. Regardless of the type employed, it must be a precision mechanism. By the use of an independent drive, or a variable-speed gear, the pitch of the recorded spiral can be made variable. In some professional models an accurate scale is fitted, which shows the exact groove at which recording begins or ends and the total playing-time. (Refs. 12; 17; 106.)

FIBROUS FILLER.—Usually flock (similar to long-staple cotton), chosen because of its properties in reducing the brittleness of the **shellac binder**, etc., used in **pressings.**

FILLER.—The insert fine-grained substance, e.g., carbon black and pigments, added to the binding material in **solid-stock** record manufacture to give weight and colour.

FILTER.—An electrical network whose essential function is to let pass desired frequency bands and to attenuate highly neighbouring undesired frequency bands. (Ref. 193; 205).

GLIDING FREQUENCY RECORD.—Recorded continuous frequency-run from, say, 8,500 c/s. to 25 c/s., with constant level above 300 c/s. See TEST RECORDS.

GRAM or GRAMME.—Metric unit of mass and weight. Equals 15.432 grains, and 0.03527 oz. avoirdupois, i.e., 30 grams approx. equals 1 oz.

GRAVITY MOTOR.—Source of power developed by a falling weight (say, 60 to 76 lb. dropping 9 ft.), to drive recording turntable. Provides the simplest, most reliable, and constant source of motive power available.

GROOVE.—The Archimedean spiral cut into the blank surface by the stylus traversing radially across the record. Also known as the Track.

GROOVE LOCATERS.—Devices that will enable a record **groove**, or part of a groove, to be located instantly with precision by the play-back needle. There are many such devices, ranging from the simple H.M.V. groove indicator to complex mechanisms, known as word-spotters. (Refs. 129; 136.)

HEADPHONES.—A pair of high-grade headphones for quality checking and monitoring has advantages in certain circumstances, e.g., permits concentration on recording material without distraction from external sounds.

HOME RECORDING.—The descriptive term popularly applied to **direct disc recording** system used by amateurs. It is a relic from the days of the deservedly short-lived acoustic toy recorders, and its continued used is deprecated.

HUM.—Is the singing note emitted from a sound reproducer, due to inadequate filtering in the high voltage a.c. supply, and inductive and capacitative coupling between the power source and some part of the audio system. The recording amplifier hum-level must be reduced to a minimum, i.e., no a.c. ripple must be discernible, even at maximum gain.

HUMIDITY.—Extremes of humidity and temperature considerably affect the performance of certain links in the recording chain, e.g., the blank, particularly the gelatinous type, and crystal cutting-heads. (Refs. 9; 157.)

INDENTATION RECORDING.—Term applied to recording on certain metal discs, e.g., aluminium, with a diamond **stylus,** in which the material is compressed to make grooves, i.e., no **thread** is removed.

INDUCTION COIL RECORDING.—Sufficient pick-up for recording both sides of a telephone conversation can be obtained by placing a suitable induction coil on the ringer box of the telephone.

JEWEL.—The stone in a sapphire **stylus** or **play-back** needle.

LAND.—The uncut space between **grooves** on a record.

LATERAL RECORDING.—The **stylus** cuts a **groove** of constant width and depth, but moves from side-to-side in accordance with the **modulation.** System commonly used for commercial **pressings** and **direct recordings.**

LEVEL.—Roughly, the sound-level or volume of sound used for recording/reproduction. The term also refers to the R.M.S. velocity of the **cutting-stylus** or **play-back needle** tip.

LINEAR VELOCITY. — The speed at which a record **groove** passes a given point. Also, Tangential Needle Velocity.

LONG-PLAYING RECORDS.—Recordings that have a playing-time considerably longer than 3½ or 5 minutes of the conventional **lateral-cut** 10 and 12 in. discs can be produced by (a) fine pitch records, e.g., 150 to 200 grooves per inch; (b) **slow-speed,** i.e., 33⅓ r.p.m. or less, records; (c) large diameter records, up to 20 in.; (d) **variable-pitch recording;** (e) constant amplitude records; (f) **constant linear velocity** system, and (g) **vertical recording.**

LOUDSPEAKER.—An electro-acoustic **transducer** designed to radiate sound waves into an enclosure or open-air. Two general types are in use to-day, namely, the direct radiator (with baffle or labyrinth), and the horn type. (Refs. 178; 183.)

LUBRICANT.—The once common practice of lubricating or waxing the surface of **direct recordings** (e.g., with a solution based on carbon tetrachloride, plus a little paraffin dissolved in it), to prolong playing-life, is not recommended these days, as such applications collect dust and add to the surface-noise. Sometimes called a Preservative.

MAGNIFYING GLASS.—A hand-glass as distinguished from a **microscope;** useful for groove examination, styli tips, etc.

MARKER GROOVE.—A groove cut to indicate end of **feed** on record.

MASTER.—In **direct recording,** refers to an oversize **blank** from which copies are to be made by **processing,** e.g., 11¼ in. for 10 in., 13¼ in. for 12 in. **pressings.** In commercial manufacture, the copper matrix obtained by **electro-plating** the original or master wax recording.

MAXFIELD, J. P., and HARRISON, H. C.—Two engineers of the Bell Telephone Laboratories, in America, who published a paper in 1926 (Ref. 34), which described a method of cutting the recording wax master electrically, and also gave the fundamental theory of the design of mechanical gramophones. It is probably the most important single contribution to the subject, as, apart from the examples of scientific design given, it disclosed the practical application of a new system based on electrical concepts for the quantitative treatment of many acoustic problems. Thus, the analogy between certain mechanical and electrical quantities can be shown: Mass (Inertia)—Inductance; Compliance—Capacity; Resistance (Friction)—Resistance.

MICROPHONE. — An acoustic-electrical convertor of sound **waveforms.** All microphones in use to-day may be classified as follows: pressure, velocity, or a combination of pressure and velocity, and directional or non-directional. Actual types currently employed for recording include (a) condenser, (b) moving-coil, (c) ribbon, and (d) crystal. (Refs. 60; 158; 183; 205.)

MICROSCOPE.—The optical device, calibrated, with magnifications, say, 60 X, sometimes mounted, on a swinging arm, and illuminated for examining record grooves, checking relation of groove to " land" (usually 60 to 40 ratio), etc.

MIL.—Equals one-thousandth of an inch. (0.001 in.)

MIXER. — An arrangement of resistance potentiometers, to regulate the inputs of several channels, e.g., **microphones, pick-ups,** when they are added together to form the transmission into another channel, e.g., the main amplifier. (Refs. 132; 158; 177.)

MODULATION. — Can be regarded as the vibration of the cutting-**stylus**, and, in turn, the recorded waveform, controlled by the electrical impulses entering the cutting-head.

MONITORING.—The process of changing the volume manually during cutting, or listening to check quality applied to cutting-head.

MOTHER. — In processing, the copper electro-plate positive made from the copper **master**, to permit the latter to be stored for safety, etc.

MUSHING DOWN. — Distortion, i.e., pushing down, of the record material by a heavy **pick-up** needle.

NEEDLE.—Needles for **play-back** may be divided roughly into three groups: (1) steel and steel-alloy; (2) non-ferrous; (3) so-called permanent (jewel type) and semi-permanent. (Refs. 66-70.)

NEGATIVE FEED-BACK. — Interconnection of the input and output terminals of an amplifier, in such a manner that the output opposes the input, which improves the frequency response and stability of the amplifier, and reduces harmonic distortion. (Refs. 142; 177.)

NON-FERROUS NEEDLE.—Any non-metallic **play-back needle,** e.g., fibre, Burmese colour, cactus, thorn. Having a high coefficient of friction, these needles are not generally recommended for playing direct recordings.

OFF-THE-AIR RECORDING.—Recording broadcast programmes by means of a separate high-quality radio-tuner, i.e., radio-frequency stage, or an ordinary radio receiver. Usually provides good quality as problems of microphones, artistes' balance, and studio acoustics are solved at transmitting end. See COPYRIGHT.

OPTICAL PATTERNS.—(See Figs. 22-24.) It should be noted that these optical tests are not of value for harmonic distortion measurement, as the pattern width depends on maximum velocity during the cycle, i.e., it is proportional to peak velocity only, which occurs at minimum amplitude where groove cuts zero axis of record groove. Plotting recorded input against reproduced output by means of a meter should give a straight line through origin, or a harmonic analyser can be used for this test (Ref. 30; 55).

OUTDOOR RECORDING. — In open-air recording attention should be paid to (a) use of low consumption valves in amplifier, fed from vibrator H.T. supply, with battery-operated pre-amplifier (where it is not possible to run even a very long mains supply connection); (b) proper use of transformers where long microphone lines used (Ref. 185) (a radio-link instead of long microphone cable might be tried, when such transmission is permissible); and (c) use of **wind-screen** for microphone (moving-coil type most suitable). (Ref. 200a).

PACKING.—To ensure undamaged delivery, when despatching by post or carrier, **solid-stock** discs, glass-base **direct recordings**, or "**masters**" for processing, great care in packing should be taken. Preferably each disc should be in its envelope, and placed between two pieces of cardboard, and the records as a batch wrapped in paper. Then the parcel should be packed in a strong cardboard box or a wooden box (if more than 5 discs) with wood wool or straw around the parcel to prevent shaking. The important point is to see that the corners are well filled with packing material, and the sides. Write "Gramophone Records—Useless if Dropped" on outside of package.

PATCH.—To join together units of apparatus, e.g., amplifiers, **equalisers**, etc., by flexible cords terminated on plugs, which are inserted into break jacks bridged across the terminations of each unit

PATCHING-IN and PATCHING-OUT.—The temporary connection (patching-in) of stand-by equipment in a circuit with patch cords, defective equipment being thereby patched out.

PICK-UP. — Device that translates mechanical motion of a needle riding in the record **groove** into electrical voltage. There are two basic types, electro-magnetic and crystal, with the former category broadly sub-divided into moving-armature and moving coil. (Refs. 17; 71-93.)

PINCH EFFECT.—May be defined as the magnitude of the up-and-down motion of the pick-up stylus tip caused by the periodic variation of the included angle between the two modulated groove walls. (Ref. 108.)

PITH.—Sapphire **styli**, when not in use, should be inserted in oil-soaked elderwood pith to prevent damage to tips.

PLASTICISERS.—Non-evaporating high-boiling liquids, used as ingredients in lacquers, to preserve flexibility and adhesive powers of cellulose layers. Examples are tricresyl phosphate, triphenyl phosphate, glycol esters, castor oil, camphor, etc.

PLAY-BACK. — The immediate reproduction from a record. Synonym, Replay.

PLAY-BACK LOSS.—Is the difference between the recorded and reproduced level in the identical radius of a record.

POINT FEELING.—A term applied to the habit that some recordists have of determining the existence of **modulation** at the **cutting-head** by touching the stylus tip with the fingers. This practice is deprecated as it may easily damage a sapphire **stylus**, and if done at all, use only extremely light pressure against the front of the stylus shank, and not the actual cutting surface.

PORTABLE RECORDER.—Recording equipment in a carrying-case, as distinguished from a console or permanent studio model.

PRE-GROOVING.—To obviate the **feed mechanism,** the original **direct recording blanks,** usually zinc, had narrow grooves cut in them by the manufacturer, which then only required to be "spread" by the cutting **stylus** movement.

PRESENCE.—Term applied to a quality of naturalness in sound recording/reproduction, so that the completeness of the illusion is such that the listener believes the sounds are being produced intimately at the **loudspeaker,** and not at some remote location.

PRESSING(S).—A disc record formed by pressure, with or with out heat. Recordings to-day are pressed in (a) **solid-stock** material; (b) **vinylite** or **cellulose acetate**; (c) laminated stock, i.e., a good grade of surface material on a Kraft paper base over a cheap core A pressing refers to the familiar gramophone record.

PROCESSING.—An inclusive term covering the involved steps of several positive-negative reversals, by means of firstly **electroplating** the master disc, to produce the final **pressing.**

RECORDER.—Term correctly applied to the equipment for recording, and not the operator, i.e., the recordist.

REVERBERATION PERIOD.—The time, in seconds, required for the decay of the sound intensity in an auditorium over an amplitude range of one million, or 60 decibels, with no emission of sound power during the decay. The less the **acoustic absorption,** the more pronounced is the reverberation; a large amount of sound absorption in an enclosure makes the reception of sounds "dead." A sufficient degree of reverberation enlivens the sounds within an enclosure and the surroundings are then said to be "live." (Ref. 183.)

RUN-IN and RUN-OUT GROOVES.—The starting and stopping spirals on discs, usually cut by a manual **feed mechanism,** which also produces the locked concentric stopping groove.

SCALE DISTORTION.—The acoustic distortion or unbalance that occurs whenever sounds are reproduced at a different level from the original. (Refs. 45; 46.)

SHADOWGRAPHING.—Individual inspection, under great magnification, of needles for playing-back direct recordings. Also known as Microspecting.

SHELLAC.—The purified product of lac, a yellow or brown coloured resinous substance produced as an incrustation on tree bark by the coccus lacca insect. Used as the chief base ingredient in **solid-stock pressings.**

SHOULDERS.—Ridges formed on the side of the needle-tip due to wear during **play-back**, causing the needle to slide over surface rather than in groove.

S/N RATIO.—In high-quality recording the speech (signal) to noise ratio is an important factor, and it is advisable to put as high an undistorted level as possible on the **blank,** which will minimise surface-noise in reproduction, and also to use correct **equalisation.** (Ref. 114).

SLOW-SPEED RECORDING.—In 33⅓ r.p.m. disc recording particular attention should be paid to (a) proper **equalisation,** as the decreased linear velocity results in squeezing-up the high-frequency **waveforms,** and (b) the use of a sapphire or stellite **stylus,** because the ordinary steel stylus will produce noisy grooves, due to the slow

linear velocity causing the coating material to tear slightly rather than cut smoothly.

SOLID-STOCK.—A loaded **shellac** composition (e.g., slate dust, 56; rosin, 4; lamp-black, 1.5; cotton flock, 0.5; plus orange lac, 22; and T.N. shellac, 16—all figures per cent.), used for the production of **pressings** in quantity. (Refs. 95-101; 163.)

SPUTTERING. — In **processing,** the method of placing the original recording in a vacuum chamber, where it undergoes electronic bombardment, i.e., a film of gold, a few millionths of an inch thick, is deposited on the record surface, thus ensuring conduction for the electrolytic copper-plating step that follows. (Refs. 97; 163.)

STAMPER.—In **processing,** the negative die (made by **electroplating** the **mother** with copper and/or chromium), which is locked in an hydraulic press and applied to the solid-stock to produce the familiar **pressing.**

STEREOPHONIC.—Term applied to reproduced sound in which the illusion of **auditory perspective** is obtained. (Ref. 107.)

STYLUS.—The tool, usually steel, stellite or sapphire, for cutting the **groove.** Sapphire styli cut a groove 4 to 6 db. quieter than the steel types, but they require more skill in use to prevent tip damage. Plural, Styli. (Ref. 69.)

SYNCHRONISING. — Methods of obtaining synchronism between picture and sound in amateur "talkies" are discussed in Refs. 116-119.

TAKE.—The making of a recording, namely, a good take, or a bad take.

TALKING BOOKS.—Ten double-sided 12 in. gramophone records, each side with a 25 minutes' playing-time, specially made for blind persons. Rotational speed is 24 r.p.m., cutting at 200 grooves per inch.

TECHNIQUE.—"Knowing all the answers," from a study of recording literature, is not enough to make a high-quality direct recording. "Practice makes perfect" applies in this work as in any other technique. It should also be remembered that a good recordist is not necessarily an engineer with high academic qualifications and years of experience. Real interest, intelligence and common sense are equally important, but the work should always be handled in an orderly, scientific manner.

TEST RECORDS. — Commercial recordings, e.g., H.M.V. DB. 1231-1245; Parlophone P. 9794-9798; Octacros Tech. 90-99; Decca Exp. 55; H.M.V. D.B. 4033-4037; and TC-17 (containing 14 selected test passages; issued to trade only), that provide a convenient A.C. source for determining the output characteristics of **pick-ups,** amplifiers, **loudspeakers,** etc., and in other sound measurements. Recommended high-quality commercial pressings, e.g., "La Boutique Fantasque," London Philharmonic Orchestra, H.M.V. C.2846-8, useful for aurally checking quality of **play-back** apparatus are given in Ref. 128.

THREAD.—The disc coating removed by the **stylus** in cutting the groove. It should be 0.002 to 0.003 in. thick., i.e., slightly thicker than an average human hair. The metal or glass-base makes the nitro-cellulose, and similar coated, blanks safe, but the thread shavings are highly inflammable, and should be disposed of, say, under water, as soon as possible. A dry can full of thread is not safe. Also known as Chip, Spew, Swarf.

THREAD CONTROL. — Methods of controlling the removed coating thread are (a) hand-brush, (b) automatic brush or chip-chaser, (c) suction device or compressed air stream, and (d) a new method of covering the blank(s) about five minutes before cutting, with a solution consisting chiefly of distilled water and leaving to dry. Other ingredients added to the solution (which largely overcomes the electro-static charge problem) are a proprietary detergent, e.g., "Aquasol" (1 drop in 0.25 pint), or a minute quantity of high-grade soap, plus a trace of colloidal graphite.

TONE.—Strictly, a sound wave of one frequency, but the term is loosely applied to any steady complex tone or musical combination of complex tones. Erroneously applied to the quality of sound reproduction.

TONE-ARM.—The coupling device between the sound-box and horn of a mechanical (acoustic) gramophone. When the so-called tone-arm was invented, to enable the horn proper to remain at rest during the traverse of the sound-box across the record, it was claimed that the tone of the reproduction was improved—hence its name. Erroneously used as a synonym for **pick-up** carrying-arm, or tracking arm.

TRACING DISTORTION.—Is harmonic distortion in record **re**production, due to the **pick-up stylus** tip size. (Refs. 47-49.)

TRAILER.—Term applied to steel **play-back** needle, so shaped that when it is inserted in **pick-up** it is inclined at a smaller angle to the record than the normal straight needle, thus reducing needle-drag and permitting direct recordings to be replayed with fairly heavy pick-ups. It should be remembered that, because the actual area of contact between needle-tip and record is so small, the final pressure for, say, a 3 oz. pick-up, against the groove, may exceed 10 tons to the sq. in.

TRANSDUCER.—Any device that accepts and delivers power associated with any kind of vibration, acoustical, mechanical or electrical. The input and output powers may be of the same or of different forms. (Ref. 183.)

TRANSFORMER.—An electro-magnetic device for separating circuits while allowing the flow of power from one to another. Also used for matching impedances. (Refs. 186; 193; 195.)

TRANSLATION LOSS.—Is the difference between the reproduced levels at two different but equally modulated radii of a record, i.e., the difference between the **play-back losses** in the two radii.

TRANSMISSION FACTOR.—Of a record, may be expressed as the ratio of **needle** amplitude to **cutting stylus** amplitude, and, although high, is not independent of frequency.

TURNTABLE.—The turntable can be considered as including the motor, which preferably should be an induction type (1/20 to $\frac{1}{4}$ h.p.) as the synchronous type, unless fitted with an elaborate damping system, is prone to "hunting," i.e., a periodic speed variation. The turntable itself should be a massive circular steel or cast aluminium plate running in a bronze sleeve bearing and a ball thrust bearing. It should be carefully machined and balanced; its mass provides the flywheel characteristic necessary for speed constancy.

TURNTABLE DRIVE.—There are many methods used to couple the motor to the **turntable,** e.g., (a) the direct drive from special low-speed motor; (b) the direct rim drive; (c) an accurate gear drive; (d) the two-speed rubber idler wheel drive; and (e) the belt drive, which is a very useful arrangement avoiding most of the disadvantages of the other methods, e.g., no transmission of motor vibration, negligible slippage, and no special tension adjustments. (Refs. 12; 17.)

UNMODULATED GROOVE.—A silent **groove,** i.e., a groove cut without **modulation** applied to the **cutting-head.**

VARIABLE-PITCH RECORDING.—An old system intended to overcome the bass cut-off and short playing-time deficiencies of the normal record. The number of **grooves** is made capable of continuous adjustment to conform to the sound **level** at any period during the actual cutting. For example, for an organ pedal note the groove pitch would be widened to, say, 50 grooves per inch, and for a violin passage the spacing would be reduced to, say, 150 grooves per inch.

VERTICAL RECORDING.—The **groove** is perpendicular to the surface of the blank, i.e., the **stylus** moves up and down with modulation, producing a groove of variable depth and, as stylus is triangular, variable width. Employed mostly for **electrical transcriptions.** Also known as Contour or Hill-and-Dale recording. (Ref. 26.)

VINYLITE.—A vinyl acetate plastic, used for making **pressings,** generally for **electrical transcription.**

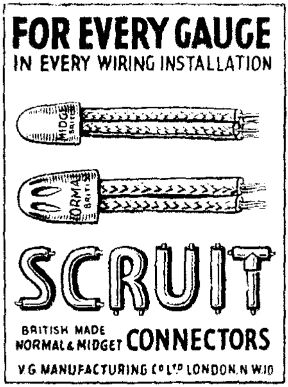
VOLUME LIMITER.—Circuit incorporated in a recording amplifier for automatic peak limiting, i.e., any sounds in excess of a predetermined level will cause an instantaneous change in amplifier gain, and reduce the volume automatically to that level. Sudden peaks are thereby prevented from causing over-cutting. (Ref. 136a).

VOLUME UNIT. — A standard of zero reference level (one milliwatt passing in a circuit of 600 ohms impedance-level) introduced by the Bell Telephone Labs. This standard permits the expression "so many decibels above or below zero reference level" to be contracted to "plus or minus VU.' (Ref. 158.)

WALLS.—The sides of a groove.

WAVEFORM.—The shape of a sound wave, as depicted graphically or reproduced in a record groove.

WEAR.—Is as much a function of the recorded waveform and the type of pick-up, needle, etc., as it is of the disc material; it is at a minimum when the mechanical impedance of the needle is nonreactive. The useful playing-life of a record, although arbitrary, is definite.



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