NEW PIEZOELECTRIC DEVICES OF INTEREST TO THE MOTION PICTURE INDUSTRY*

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High-Fidelity Record Cutter.—Basically, a Brush crystal unit is an ideal driver for a record cutter due to its inherent great stiffness. Due to this stiffness, its amplitude and frequency response are almost completely unaffected by depth of cut, variations in hardness of the record blank, *etc.*

Normal recording practice calls for constant velocity over most of the range. This means that the amplitude will increase as the frequency decreases. As this would call for too wide spacing of the grooves if carried on down to, say, 30 cycles, it is customary to change to constant amplitude for frequencies below somewhere between 250 and 1000 cycles. A crystal-operated cutter will tend to give constant amplitude at all frequencies. This is modified by including in the cutter circuit sufficient resistance, either mechanical or electrical, or both, to attenuate the higher frequencies. As the load presented by the crystal itself is similar to a condenser, its impedance will decrease with increase of frequency, therefore the higher the frequency, the greater the attenuation produced by the series resistance.

Fig. 1 shows the construction of the new crystal cutter, type *RC-1*. A large four-ply crystal unit ($2^1/_2 \times 1 \times {}^1/_4$) is used to drive the stylus. This is considerably larger than necessary and provides a large factor of safety as the crystal will stand 500 volts, while the normal recording in the constant or maximum amplitude part of the range requires about 50 volts. At higher frequencies the voltage will be proportionately less. Total power consumption is a fraction of a watt.

Fig. 2 is a photograph of the "Christmas tree" pattern from 30 to 12,000 cycles made by applying constant voltage to an *RC-1* with appropriate series resistance to cut at constant velocity above 300 cycles; while Fig. 3 is a curve of the output of a *PL-12* pick-up and filter on this same record.

PL-12 and PV-12 Phonograph Pick-Ups.—These two pick-ups are similar in construction, the only difference being that the *PL* was designed for lateral recordings and the *PV* for vertical recordings. The main objective in their design was to produce a rugged reliable device with flat response to at least 10,000 cycles, in which the wear on the record would be reduced to a minimum. This called for an extremely light flexible stylus and a consequent sacrifice in output. On open circuit, the output of this pick-up is proportional to amplitude, irrespective of frequency, but when fed into a resistance load lower than its own impedance at any frequency, the output will be proportional to velocity. In order to correct for the fall-off that would occur at the constant-amplitude portion of a recording, all that is necessary is to place a capacity in series with the resistance load so that the load impedance will increase correctly at these low fre-

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quencies and result in correct input to the amplifier down to 30 cycles without further compensation.

Fig. 4 shows the construction of the pick-up. A sapphire stylus is set in a small screw which fits the thread in a hollow magnesium chuck. The motion

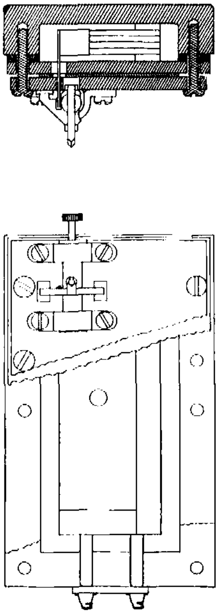

FIG. 1. Brush type *RC-1* record cutter.

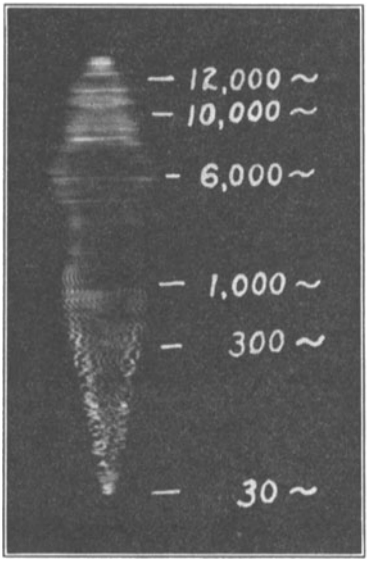

FIG. 2. "Christmas Tree" pattern, from 30 to 12,000 cps.

of this chuck is converted into torsional strain in a beryllium bronze wire which conveys a twisting force to the crystal in a hermetically sealed compartment. This twisting force is exactly in proportion to the deflection of the stylus and is converted into electrical energy by the crystal.

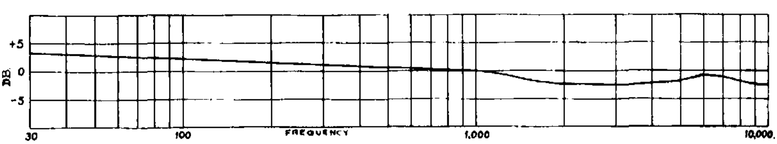

FIG. 3. Overall response of Brush *RC-1* cutter and *PL-12* pick-up on direct acetate recording, constant input voltage to cutter.

Fig. 5 shows some of the mechanical characteristics of the system. Curve *1* shows the amplitude of the cut on an average record for a constant high output at all frequencies and assumes the amplitude to become constant below 250 cycles. The force required to overcome inertia in rotating the stylus and stylus-arm assembly at constant amplitude is proportional to the square of the frequency, and depends upon the moment of inertia of the assembly. Due to the decrease in amplitude above about 250 cycles, the force required will vary directly with frequency, as shown in Curve *2*. The stiffness or restoring force of the beryllium bronze wire and its composition bearings has maximum effect at the low frequencies and was designed not to exceed greatly the force required to overcome inertia at the high end. In any oscillatory system, the natural period is a function of the moment of inertia and the restoring force. When the stylus is not in contact with the record, this occurs at about 2000 cycles. At this frequency a minimum side pressure is exerted by the record when the stylus is in the groove. Curve *3* shows the restoring force plotted against frequency and Curve *4*, the damping component. Curve *5* shows the pressure required from the side wall of

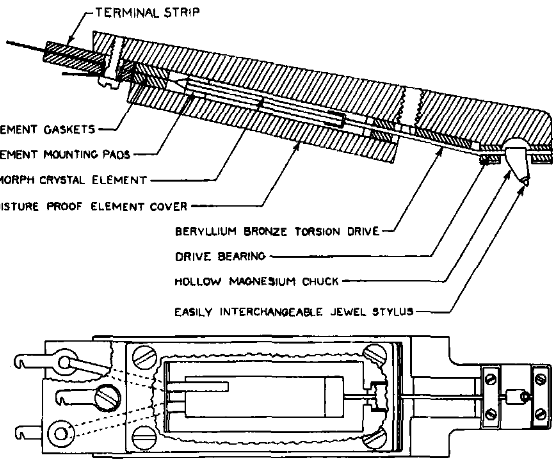

FIG. 4. Type *PL-1* high-fidelity phonograph pick-up.

the record groove to move the stylus, having constant output at all frequencies. The weight of the stylus and stylus-arm assembly is approximately 0.005 ounce. From Curve *5* it will be seen that the maximum side pressure on the stylus is about 0.18 ounce at the low end, falling to a minimum and then rising to a little over 0.1 ounce at 10,000 cycles. The natural period of the crystal is over 14,000 cycles. Due to these small forces it is possible to use as little as 0.5 ounce of weight on the head and the wear on the records and stylus is extremely low.

Fig. 6 shows the values of the correcting filter supplied. The filter is arranged to give three sets of values and the curves show the effect on the response from a Victor 30- to 10,000-cycle test-record.

Standard shellac pressings may be played as many as 3000 times without appreciable wear on record or stylus. Direct nitrate recordings may be played hundreds of times, but what is possibly more important is that it is possible to play back from the soft nitrate direct recordings frequencies up to over 12,000

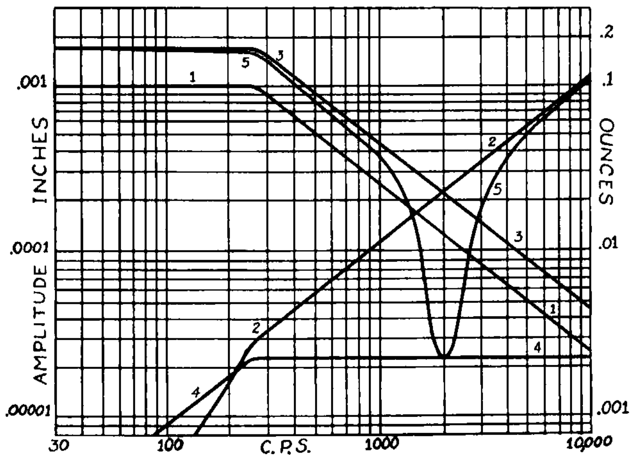

FIG. 5. Pressure from side wall of groove to move stylus.

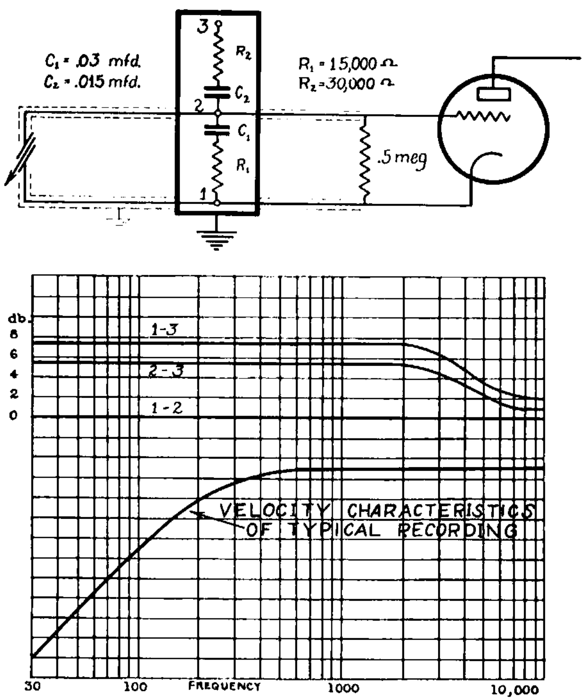

FIG. 6. Values of correcting filter.

cycles. This is not possible without serious loss of the higher frequencies with an ordinary pick-up due to the inertia of the heavy moving parts.

Unidirectional Microphone.—The unidirectional microphone, Type *UD-4*, obtains its unidirectional characteristics by combining a nondirectional or pressure microphone with a bidirectional or pressure-gradient (or velocity) microphone resulting in a cardioid-shaped field.

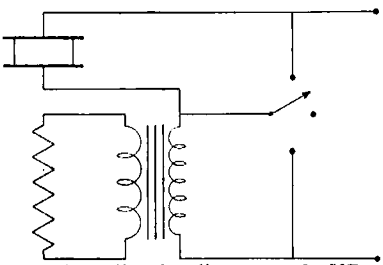

FIG. 7. Circuit diagram of *UD-4* microphone.

To obtain correct addition of the outputs from the two elements for sounds originating from the front, and cancellation from the rear, the outputs must be equal and in correct phase relationships.

A few years ago, Brush brought out their Type *UD-3* unidirectional microphone in which the pressure-gradient unit consisted of two sets of opposed pressure cells whose outputs and phase relations had to be corrected before mixing with the straight pressure cell. This called for a special and complicated amplifier or, if done before amplification, a rather low output. In the new instrument, Type *UD-4*, a ribbon microphone replaces the differentially connected pressure units. The stiffness-controlled capacity pressure unit is in phase with the mass-controlled inductive velocity unit without compensation.

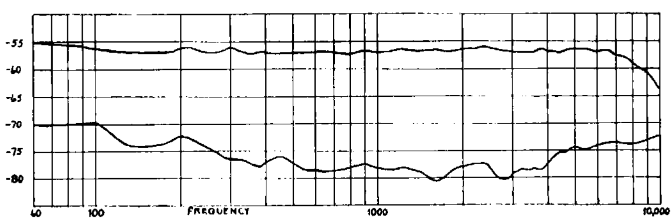

FIG. 8. Response characteristic of *UD-4* unidirectional microphone, front and back.

Fig. 7 shows the arrangement diagrammatically. To match outputs, the ribbon is stepped up to a convenient impedance by means of a transformer whose secondary is in series with the sound cells, which are placed in the same vertical plane as the ribbon. A switch is provided to cut out one or the other, making the microphone unidirectional, nondirectional, or bidirectional at will. A fourth position also is provided to cut in an appropriate resistance to reduce the bass for close speaking. The sound cells are so placed in the case that the natural position for close speaking is much closer to the sound cells than the ribbon in order to minimize the familiar bass accentuation common to a velocity unit in a spherical wave.

Fig. 8 shows a typical response curve from the front and rear of this microphone, switch in *UD* position.

The microphone is relatively small and compact, as it does not require the acoustical labyrinth that is necessary when a ribbon pressure unit is used. The output is quite high, being about −54 db. (zero equals 1 volt per dyne per sq.-cm.) from the front (unidirectional position) with the high-impedance model. A low-impedance model will also be available with slightly lower output. The average difference back to front is 10 to 1.

High-Fidelity Head-Phones.—The Type *A-1* phones were primarily designed for monitoring in film and broadcast studios and for testing hearing. They are similar to Type *A* phones in appearance and weight. Fig. 9 shows a cross-section

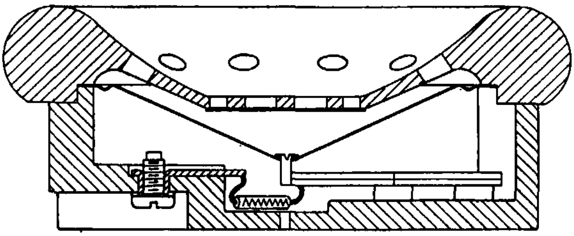

FIG. 9. Type *A-1* high-fidelity receiver.

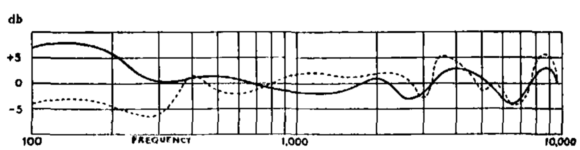

FIG. 10. (Solid curve) pressure calibration; (broken curve) subjective calibration.

of the unit. Great care has been taken to correct serious dips and peaks in the response curve, resulting in very uniform output from 100 to 12,000 cycles. They have been made extremely sensitive to the higher frequencies (*i. e.*, with a rising characteristic) which have been again reduced to normal by means of a high series resistance (150,000 ohms) in each unit. This resistance, besides aiding uniformity of response, guarantees that the phones will have no effect on the line across which they may be shunted.

As is well known, a very small air leakage between phone-cap and ear will cause serious loss at the lower frequencies. This loss has been somewhat compensated for in the Type *A-1* phones and Fig. 10 shows typical response curves taken on an artificial ear and taken subjectively.

The voltage sensitivity is approximately one volt per dyne, which is satisfactory for use at zero level on a 500-ohm line. For great sensitivity it is perfectly satisfactory to use a step-up transformer wound for, say, 5000 ohms to 50,000 ohms or 80,000 ohms, without impairing quality or affecting the line. Each unit weighs two ounces and they are extremely rugged.