March 7, 1944. O. KORNEI 2,343,417

PHONOGRAPH PICKUP

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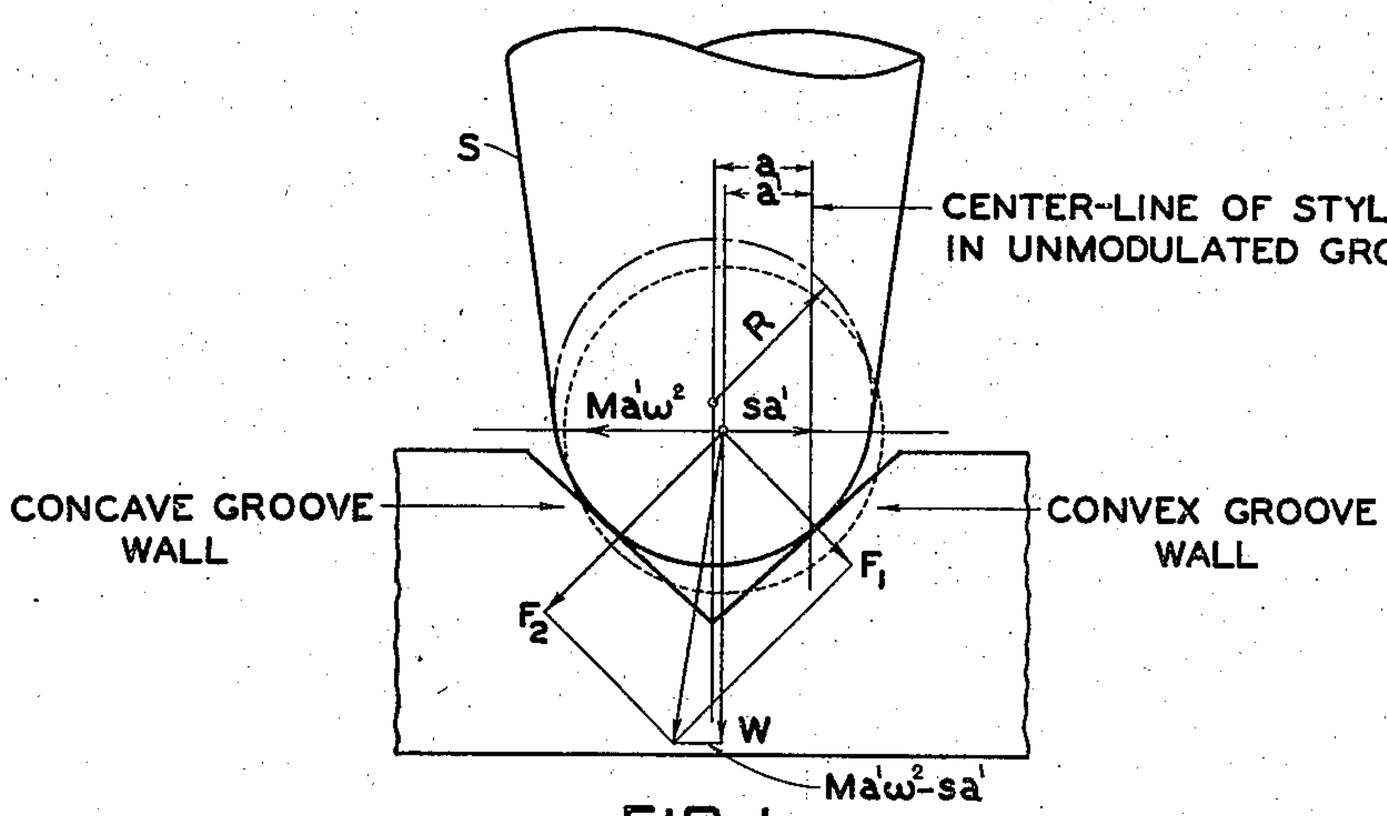

FIG. 1

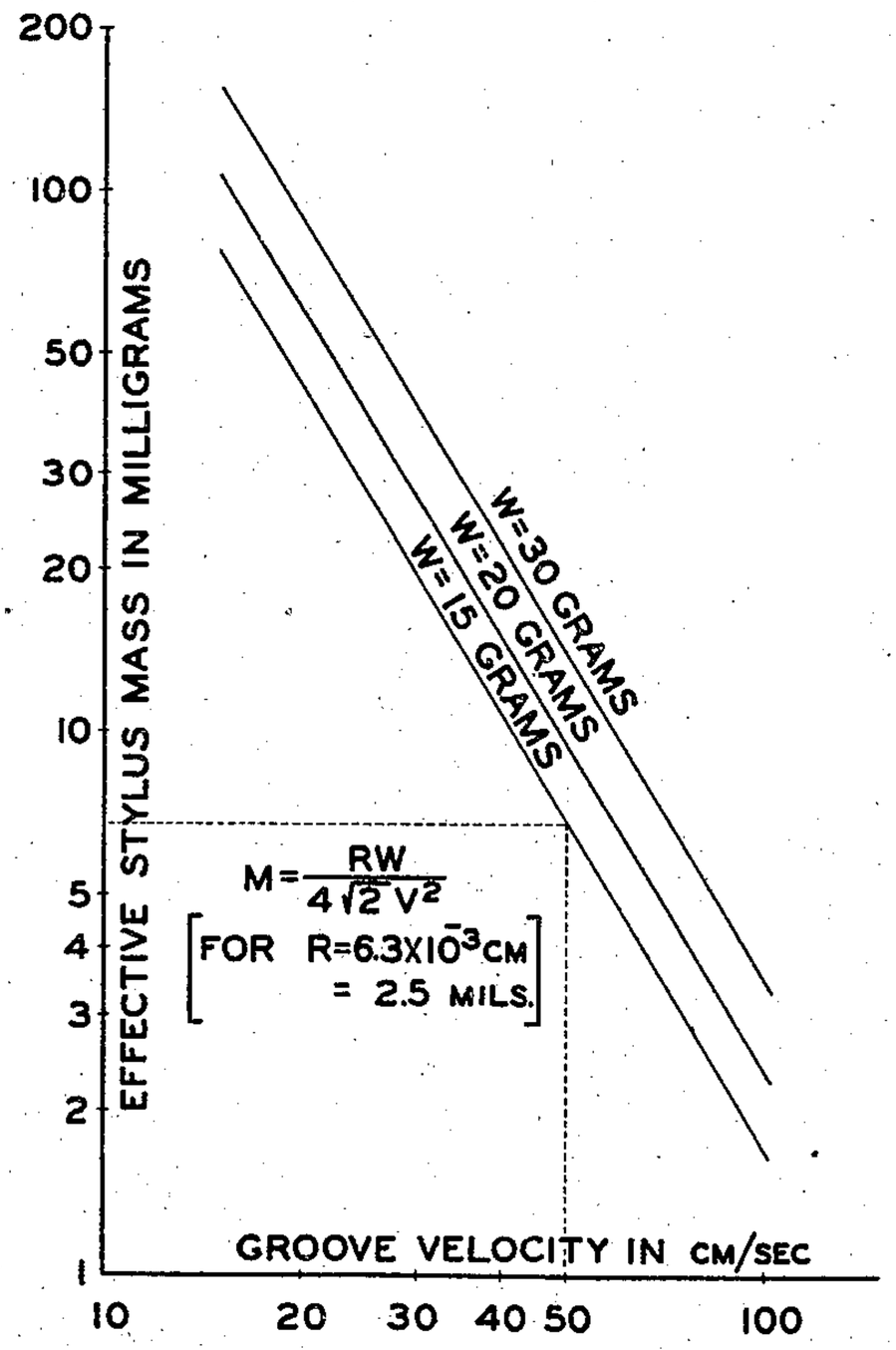

FIG. 2

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PHONOGRAPH PICKUP

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4 Claims. (Cl. 274—1)

This invention relates to phonograph pickups and, more particularly, to pickups for utilization in combination with phonograph records of the lateral cut, pressed or embossed types, the groove velocity of which with respect to the stylus is maintained constant during the playing thereof.

The primary object of the invention is to provide a pickup, of the type described, that shall exhibit no frequency discrimination over a wide range of audio frequencies.

It has been known for some time that there are a number of inherent difficulties which seriously interfere with the faithful reproduction of sounds in the upper frequency range from laterally modulated phonograph records. In particular, it has been observed that the reproduced level at the higher frequencies deviates from the level to be expected from the recorded modulation despite the employment of linear translating devices. Such deviations depend upon the elastic properties of the record material, the linear groove velocity and the physical constants of the pickup.

Previous to this invention, a number of complicated attempts were made to overcome the playback loss of level, including overemphasizing the upper frequency range during the recording process, as well as utilizing a pickup or amplifier system having a rising frequency characteristic. Such attempts have been more or less successful with a given record material; they fail, however, when records having differing elastic properties are indiscriminately reproduced through a system designed around one particular material. The drawbacks of known systems are especially apparent since the advent of the so-called "instantaneous" recording methods and systems because such systems utilize record materials that are considerably softer, i. e., more compliant than the materials such as shellac, etc., employed for commercial pressings.

As pointed out in an article by the inventor, which appeared in the Journal of the Society of Motion Picture Engineers, volume 37, December, 1941, on pages 569 to 590, the exact correlation between the playback losses, on the one hand, and the physical constants of the record material and the translating device, or pickup, on the other hand, had not been determined previous to this invention. In the article referred to, which discloses the invention, an equation is derived which permits the mathematical prediction of the playback loss for any recorded frequency, and reference may be made to the said article for further details, if desired.

In accordance with the invention, a pickup device is provided which is related to the constant groove velocity V, expressed in centimeters per second, according to the formula

$$\frac{RW}{M}=4\sqrt{2}V^2$$

wherein R is the radius of the spherical stylus tip, expressed in centimeters, W is the steady vertical force acting on the record, expressed in dynes, and M is the mass, effective at the center of the stylus tip, of the stylus and the associated vibratory system, expressed in grams.

The novel features considered characteristic of the invention are set forth with particularity in the appended claims. The invention itself, however, both as to its organization and its method of operation, together with additional objects and advantages thereof, will best be understood from the following description of a specific embodiment, when read in connection with the accompanying drawing in which:

Figure 1 is a greatly enlarged schematic view in vertical cross section exemplifying the engagement of a stylus tip with the walls of a record-groove at the position of maximum excursion of the stylus, and

Figure 2 is a graph representing the mathematical formula expressing the invention.

Referring now to Figure 1, if a stylus S, having a tip-radius R, is caused to engage the sidewalls of the groove in a laterally modulated record, it exerts a force F_1 on the concave wall and a force F_2 on the convex wall. The angle between the walls at the bottom of the groove is assumed to be 90°; the assumption of some other angle changes only the numerical constants in the equation which will be presented hereinafter.

The respective forces, F_1 and F_2, acting between the stylus tip and the groove walls are resultants of the steady vertical force W, and the horizontal forces caused by the lateral acceleration M a' $4\pi^2f^2$ and the lateral displacement s a' of the stylus as a result of the modulation of the groove at a frequency f. These forces tend to deform the groove walls elastically and, consequently, the stylus assumes a lateral position that is different from the position it would assume were the record material perfectly rigid. The resultant forces are not equal and the convex wall of the groove, in general, is deformed more than the concave wall thereof. The stylus tip, therefore, takes a position indicated by the dotted circle in the drawing.

In Figure 1, a represents the excursion of the stylus were the material perfectly rigid and a' the excursion thereof occasioned because of the elastic deformation of the sidewalls of the groove. The difference between the lateral component of the deformation of one sidewall and the lateral component of the deformation of the other wall determines the loss in playback level, i. e., the difference $(a-a')$ between the recorded and reproduced amplitude during the reproduction of sound from the record.

It is also a fact, as pointed out in the article referred to, that if the other parameters remain unchanged, the steady vertical force on the record and the stylus stiffness contribute to greater playback loss, while the effective mass of the stylus contributes to a reduction of the loss.

The playback loss L, in decibels, may be expressed by the following formula, the derivation of which is given in the cited article:

$$L=20\log\left\{1+K\left(\frac{W^2}{E^2R}\right)^{\frac{1}{3}}\left[4\pi^2f^2\left(\frac{R}{4\sqrt{2}V^2}-\frac{M}{W}\right)+\frac{s}{W}\right]\right\}$$

In the above expression, K is a numerical constant, W is the steady vertical force exerted by the pickup device on the record, E is the elastic modulus of the record material, R is the radius of the spherical tip of the stylus, V is the constant groove velocity, M is the mass of the stylus as effective at the center of the stylus tip, f is the frequency of the modulation of the groove and s is the lateral stiffness of the stylus system.

Inasmuch as the primary object of the invention is to provide a pickup system wherein the playback loss shall be independent of frequency, it is accomplished by so proportioning certain of the elements thereof that the term in the foregoing equation associated with the frequency vanishes, i. e., that

$$\frac{R}{4\sqrt{2}V^2}-\frac{M}{W}$$

becomes equal to zero. This expression can also be written as:

$$M=\frac{RW}{4\sqrt{2}V^2}$$

The general formula for any angle 2β between straight side walls is

$$M=\frac{RW\cos\beta}{4V^2\tan\beta}$$

It can be seen that this general formula evolves into the special formula

$$M=\frac{RW}{4\sqrt{2}V^2}$$

if it is assumed in the special formula that 2β is equal to 90 degrees.

Because of the fact that the stylus radius R and the steady vertical force W are pickup constants, it follows that for any given record velocity V there is a definite stylus mass for which the playback loss becomes independent of frequency and, consequently, for which there is no discrimination against any particular frequency during reproduction. In the article cited, it is proved that the so-called pinch effect is so small that it may be neglected in connection with the foregoing considerations. Another important feature is the fact that the relationship expressed in the immediately preceding equation holds good for any record material, since neither the modulus E, nor any function thereof appears therein.

It will be obvious from the foregoing that the invention is of considerable value in connection with the reproduction of sound from a lateral cut record of any physical type, such as an endless strip, or a record of either the disc or cylinder variety, when such a record is so driven that the velocity of the groove with respect to the stylus is constant. Faithful reproduction, without frequency discrimination can be obtained from such records if the pickup device is proportioned according to the invention and this result, in addition, is entirely independent of the record material.

It is assumed, of course, that the stylus is related to the entire vibratory system of the pickup device, whether electrical or acoustical, in such predetermined manner that the output from the pickup is independent of the frequency of the stylus excursions. In other words, the pickup itself is inherently "linear."

In order to disclose further the invention, practical values are shown in Figure 2, which figure is a graphic representation of the basic formula. The said figure shows the required stylus mass M as a function of the record groove velocity for three different values of the steady vertical force W, the rather common stylus radius, 2.5 mils, being assumed as R in the formula.

To utilize the graph, for example, in the design of a pickup to be employed with a record for reproduction at a constant groove-velocity of 50 cm. per second, an effective stylus mass of about 6.5 milligrams would be required if the steady vertical force W corresponds to a mass of 15 grams. This correlation is indicated by the dotted lines.

Inasmuch as the invention resides in the proper correlation of certain parameters of the record-pickup combination, obviously those skilled in the art will be able, without departing from the spirit of the invention, to evolve graphs and formulae relating specifically to every possible type of groove-contour. This fact is appreciated, but it is obviously not feasible to include all of such graphs and related formulae herein. The invention, therefore, is not to be restricted except insofar as is necessitated by the prior art and by the spirit of the appended claims.

What is claimed is:

1. In a pickup for utilization in combination with a laterally modulated sound record of the constant groove-velocity type in which the side walls of the groove are straight and define substantially a 90 degree angle; a vibratory system including a stylus adapted to be moved by the modulated walls of the groove; the mass (M) of the stylus system effective at the center of the stylus tip, the radius of curvature of the said stylus tip (R), the steady vertical force (W) exerted on the record by the stylus, and the constant velocity (V) of the record groove being related substantially according to the formula:

$$M=\frac{RW}{4\sqrt{2}V^2}$$

2. The invention set forth in claim 1, characterized in this: that the force (W) is less than that force which will cause permanent deformation of the record groove when applied thereto by a stylus having the designated tip-radius (R).

3. In a pickup for utilization in combination with a laterally modulated sound record of the constant groove-velocity type in which the side walls of the groove are straight; a vibratory system including a stylus adapted to be moved by the modulated walls of the groove; the mass (M) of the stylus system effective at the center of the

stylus tip, the radius of curvature of the said stylus tip (R), the steady vertical force (W) exerted on the record by the stylus, and the constant velocity (V) of the record groove being related substantially according to the formula:

$$M=\frac{WR\cos\beta}{4V^2\tan\beta}$$

where β is one-half of the angle between the side walls of the groove.

4. The invention set forth in claim 3, characterized in this: that the force (W) is less than that force which will cause permanent deformation of the record groove when applied thereto by a stylus having the designated tip-radius (R).

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