March 8, 1955 C. H. ALLEN 2,703,874

ELECTROMAGNETIC VIBRATOR

Filed Jan. 17, 1951

FIG. 1

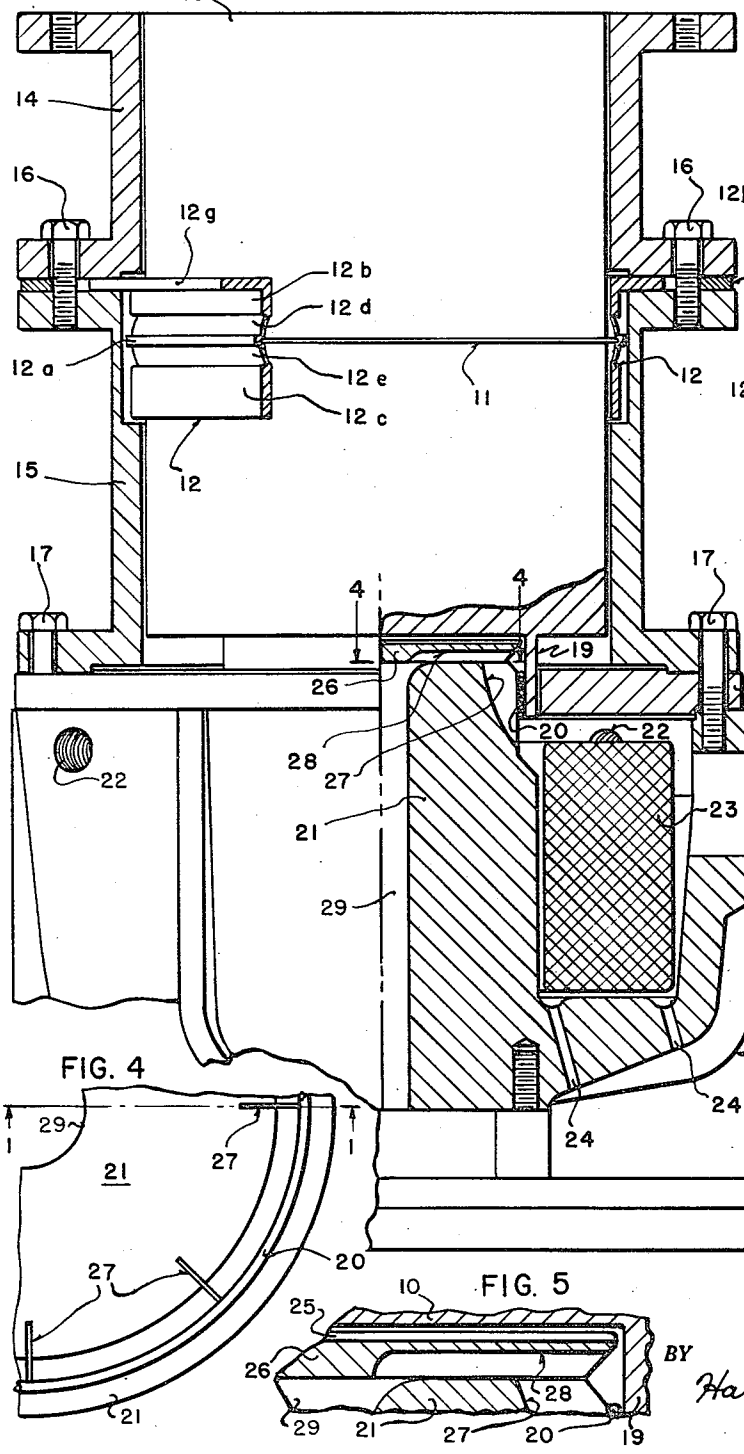


FIG. 2

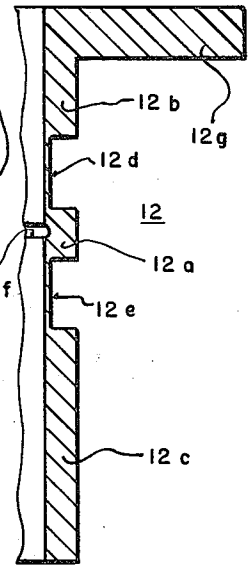


FIG. 3

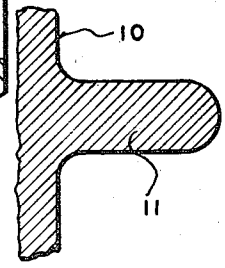


FIG. 4

FIG. 5

INVENTOR.
CLAYTON H. ALLEN

BY Harry M. Saragovitz
Attorney

United States Patent Office

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ELECTROMAGNETIC VIBRATOR

Clayton H. Allen, Corning, N. Y., assignor to the United States of America as represented by the Secretary of the Army

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8 Claims. (Cl. 340—12)

This invention relates to improvements in electromagnetic vibrators for the generation of high frequency sound.

Examples of electromagnetic vibrators of the specific type and application to which the present invention relates, are disclosed in Patent No. 2,432,218 issued December 9, 1947, to Alfred Vang, and in an article by Hillary W. St. Clair entitled An Electromagnetic Sound Generator for Producing Intense High Frequency Sound. This article is on pages 250 to 256 of the May 1941 issue of The Review of Scientific Instruments, the latter being a monthly journal published by the American Institute of Physics, New York, New York. In this article, the vibrating element of the generator is described as being a solid cylinder of Duralumin supported at its midsection and free to vibrate longitudinally as a free-free bar. It is excited into vibration electromagnetically in a manner similar to that used with a dynamic loudspeaker. The manner of supporting the vibrator can have a very great effect on mechanical losses. Although the midsection of the vibrator has been considered a nodal plane, this is true only for purely longitudinal vibrations. Because of the lateral contractions that must accompany longitudinal extension, a rod cannot execute purely longitudinal vibrations. The relative magnitude of the accompanying lateral contractions increases with the diameter of the bar. Consequently, when the supporting web of the vibrator is tightly clamped, the vibrator is heavily damped. This difficulty was overcome in large part by placing rubber shims, wrapped in aluminum foil, between the annular web and the supports. The rubber shims permitted a slight radial movement of the vibrator without excessive losses, and the aluminum foil served to ground the vibrator to the housing therefor. The boundary conditions necessary to permit rigid clamping at any point on a free-free bar cannot, in general, be simultaneously satisfied. A solution is possible only for a bar whose diameter bears a certain definite ratio to its length. On the other hand, in allowing for some degree of radial vibrations, there results a slight reduction in the resonant frequency.

Among the objects of the invention is the provision of an improved electromagnetic vibrator of the character referred to which has advantages over the various constructions proposed heretofore in the way of greater output and increased efficiency.

Another object resides in the provision of an electromagnetic vibrator of the character referred to which is very sharply tuned, which puts out a sinusoidal wave, and wherein the parasitic noise is negligible.

Other objects and advantages will hereinafter appear.

For the purpose of illustrating the invention an embodiment thereof is shown in the drawing, wherein

Fig. 1 is a view partly in elevation, partly broken away, and partly in section, the section being taken in a vertical plane through the longitudinal center of the vibrator and in the plane of the paper, and on line 1—1 in Fig. 4;

Figs. 2 and 3 are enlarged, detail, sectional and fragmentary views of two of the parts;

Fig. 4 is an enlarged, detail, fragmentary view taken on line 4—4 in Fig. 1; and

Fig. 5 is an enlarged, detail, sectional and fragmentary view taken from Fig. 1, the section, as in Fig. 1, being taken on the line 1—1 in Fig. 4.

Numerals specified in the following description are representative dimensions in inches.

In Fig. 1, the reference numeral **10** designates the vibrating element of the sound generator, the former being in the form of a solid cylindrical bar of Duralumin or other material of low mechanical loss in vibration, supported at its midsection and free to vibrate longitudinally as a free-free bar. Use of a vibrator bar supported as shown and 6.52 in length and 4.80 in diameter has given satisfactory results.

An important structural characteristic of the improved sound generator resides in the means and manner of supporting the vibrator bar **10**. A thin web **11** which extends entirely around the cylindrical surface of bar **10**, is disposed substantially at the center thereof near the nodal plane. As shown more clearly in Fig. 3, the web **11** is an integral part of the vibrator bar and may be machined from the Duralumin piece in making the latter. Around the mid-section of bar **10** is a mounting or vibrator-support ring **12** provided with a groove **12*f*** cut in the inside surface of the latter and extending circumferentially around the same to receive web **11**. Ring **12** is shrunk on to the thin web **11** cut from bar **10** at its nodal plane. Also, the ring **12** is cut undersize so that when it is heated, positioned as shown in Fig. 1, and then shrunk by cooling, it is under sufficient initial tension to follow the lateral vibrations of the bar and remains in contact with the web **11** without chattering even at the largest amplitudes employed. In operation of the sound generator, the mid-section **12*a*** of ring **12** follows the vibrator bar **10**, while its top and bottom sections **12*b*** and **12*c*** remain substantially stationary. The two relatively thin sections **12*d*** and **12*e*** of the ring furnish sufficient compliance to allow the motion described without over-stressing the metal or allowing parasitic vibrations. Since the mounting ring **12** is relatively small compared with the vibrating bar **10**, is made of the same metal as the latter, and is subject to stresses of the same order of magnitude as those in the bar itself, there are relatively small losses of energy in this type of support. In the specific vibrator bar aforesaid, the web **11** has an outside diameter of 4.940 and extends beyond the cylindrical surface of bar **10** a uniform distance of .070. Before assembly and as in Fig. 2, the center-line diameter of groove **12*f*** into which web **11** fits, is 4.928. Depth of this groove is approximately .002, and its radius is approximately .020, i. e., slightly greater than the corresponding radius of the web which is approximately .015.

Surrounding the vibrator bar **10** is a metal jacket comprising the two similar, cylindrical parts **14** and **15** secured together by stud-bolts **16** and between which is clamped the flange **12*g*** integral with and extending outwardly from ring **12** at the upper end of the latter, as shown in Figs. 1 and 2. Bar **10** is thereby supported peripherally along the center of its cylindrical surface where there is a vibration node. Since the flange **12*g*** does not extend past stud-bolts **16**, spacers **12*h*** of the same thickness as flange **12*g*** are employed between the complementary flanges of housing parts **14** and **15** in order to prevent vibration of the latter. If flange **12*g*** is made to extend radially outwardly beyond stud-bolts **16**, the circumferential portion of the flange serves the purpose of spacers **12*h*** and accordingly makes use of the latter unnecessary. The jacket or housing **14**, **15** supports the vibrating bar **10** and positions it accurately and rigidly with respect to the magnet while at the same time preventing sound radiation from the side of the bar. When auxiliary equipment such as a reflecting plate or resonant chamber is mounted on the jacket or housing, such plate or chamber must be accurately located with respect to the vibrator.

Located below the vibrator and secured by stud-bolts **17** to housing **14**, **15**, is a large pot magnet designated generally by the reference numeral **18**, and which drives the vibrator in much the same way as a loudspeaker is driven. A ring **19** machined from, and therefore integral with the vibrator, functions as a voice coil of a single turn. Current is induced into ring **19** by an auxiliary, stationary coil **20** of approximately thirty turns wound directly on the center pole-piece **21** of the pot magnet. The top plate or annular pole-piece **18*a*** of the

magnet **18** is disposed and clamped between the housing part **15** and the magnet housing, as shown in Fig. 1.

Continued operation of the vibrator at high power is made possible by cooling air which is forced into the pot magnet through a suitable number of inlet openings **22**, circulates through the specially wound field coil **23** and over voice coil **20**. The air passing through the field coil leaves through several small openings **24** in the bottom of the magnet housing, and that which passes over voice coil **20** leaves through the hole or outlet passage **29** drilled axially through pole-piece **21**.

In order to effect air-cooling of each turn of wire of the field coil at several points per turn and without greatly increasing the size of the coil, spacers are placed between adjacent layers as the coil is wound on a spool made in several parts bolted or otherwise secured together for release and removed after the winding operation, to leave the complete coil. Passages between the adjacent layers of coil **23** are thereby provided. The spacers are placed about each layer before winding on the next layer. They may be of wire approximately the same diameter as the wire of the coil, and slightly greater in length than the distance between the two circular end plates of the spool so that the ends of the wire spacers will extend into and be positioned by radial slots cut into the end plates. A set of four such spacers is used between adjacent layers. Each of the four spacers of a set is placed against the layer just wound, parallel to the spool axis. Satisfactory results have been obtained by placing the four spacers 90° apart, one from the other, and staggering the successive groups or sets of spacers with respect to each other, radially about the spool axis. For example, looking along the axis of the spool and at one end thereof, the four spacers on the first layer might be, respectively, at the north, east, south, and west positions. The four spacers on the second layer might be, respectively, at the north northeast, east southeast, south southwest, and west northwest positions. And so on for succeeding layers, the radial staggering of the spacer groups or sets being chosen to insure a uniform distribution of passages through the field coil **23**. In general, the number of spacers used will depend upon their size, the size of the field coil being wound, and the number of spacers desired per layer. The number of spacers per layer is determined by the requirement for uniformity in temperature. The design yields a number of contacts per turn between the cooling fluid and the wire equal to twice the number of spacers per layer. The approximate size of the spacers is determined by the circulating fluid, operating pressure, and freedom from dust or other solid contamination. For a high-pressure system with dust-free fluid, very small spacers may be used and very complete cooling accomplished with little loss in the cross-section of the copper.

In operation of the improved sound generator, field coil **23** is energized in the conventional manner by a steady direct current. The voice coil is energized by an alternating current whose frequency is the same as the resonant frequency of the vibrating bar. The wave form of this current is unimportant and may be anything from short pulses to a sinusoidal form; the vibrating bar will, in any case, execute sinusoidal oscillations with negligible distortion because of its highly resonant character. However, because of this highly resonant character, the frequency of the applied current must very precisely match the mechanical resonance frequency of the bar. This match is accomplished by means of electrical feed-back obtained from a condenser pick-up composed of a stationary plate **25** and a moving plate formed by the lower surface of the vibrating bar **10**. The feed-back may be utilized by one of several conventional control circuits (not shown) to maintain the frequency of the driving current equal to resonance frequency of the bar at all times even through the latter may drift widely due to changes in operating temperature or loading. The stationary plate **25** of the condenser pick-up is secured to the central pole piece **21**, but insulated from it by a suitable insulating plate **26** so that the plate **25** may be biased with a convenient high, D.-C. voltage with respect to the vibrating bar. The insulating plate **26** is provided with a number of radial grooves **28** to allow passage of the cooling air from coil **20** to the exit hole **29**.

For the purpose of decreasing eddy currents produced by the alternating current in coil **20**, radial slots **27** are cut in the center pole-piece **21**. Like slots may also be cut for the same purpose into the inner edge of the annular, outer pole-piece **18***a*. These slots are made as narrow and deep as practicable. In the specific sound generator aforesaid the slots **27** were eight in number and equally spaced as shown in Fig. 4, the width of each being .010 and the depth and cross-sectional area of each being substantially as shown in Fig. 1. In the specific sound generator aforesaid, the depth of each groove **28** was .125 and the width of each was .1875.

The improved construction disclosed herein, as a practical embodiment of the present invention, supports the vibrator bar **10** around its periphery near the nodal plane while, at the same time allowing essentially no damping to radial vibrations and/or to slight longitudinal vibrations at this plane due to unavoidable departure of the plane of support from the nodal plane. The improved construction, furthermore, provides adequate support for the vibrator bar **10** as well as accurate positioning thereof in any orientation of the entire unit, and also provides a gas-seal between the two halves of vibrator bar **10** when the device is clamped into a suitable retaining wall.

While but one embodiment of the invention has been shown and described, it will be understood by those skilled in the art that various modifications, such as in the size, shape and arrangement of the parts, are possible without departing from the spirit of the invention or the scope of the claims.

What is claimed is:

1. In an electromagnetic vibrator of the character described, a cylindrical vibrator bar provided with a relatively thin web substantially at the center thereof near the nodal plane and extending outwardly from the cylindrical surface of said bar and entirely around the same, and a ring disposed about and spaced from said bar; said ring comprising a mid-section, top and bottom sections, and relatively thin sections disposed respectively between said mid-section and said top section and between said mid-section and said bottom section; said mid-section being provided in and entirely around the inside surface thereof with a groove accommodating said web with a relatively close fit whereby said bar is supported by said ring only in the plane of said groove and said web disposed in said groove, the center-line diameter of said groove being undersize with respect to the corresponding dimension of said web and said ring having a shrunk-on fit about said bar at said web and groove, to place said ring under initial tension.

2. In an electromagnetic vibrator of the character described, a vibrator bar provided between the ends thereof with a relatively thin web disposed about said bar and extending radially outwardly from the surface thereof, and means providing the sole support for said bar; said means comprising a metallic ring disposed about said bar at said web and provided in its inside surface with a groove, said ring being shrunk onto said web with the latter disposed in said groove, said ring also including a stationary portion for supporting said bar and a flexible, constricted portion joining the stationary portion with the portion thereof having said groove.

3. In combination with a vibrator bar having a peripheral, outwardly extending web, a support for said bar comprising a metallic ring surrounding said web, said ring having a first portion clamped to said web and movable with said bar, a stationary second portion for supporting said bar, and a flexible third portion joining said first and second portions whereby said second portion is caused to remain stationary during vibration of said bar.

4. The combination set forth in claim 3, in which said first portion includes a groove on the inner surface thereof in which said web is disposed, and said third portion is of constricted cross-section with respect to said first and second portions.

5. The combination set forth in claim 4, in which said ring is formed of the same metal as the vibrator bar.

6. In combination with a solid cylindrical vibrator bar having an annular, outwardly extending web near the nodal plane thereof, a support for said bar comprising a ring having a portion clamped to said web and movable with said bar, said portion including a groove on the inner surface thereof in which said web is disposed, a constricted, flexible annular portion extending from each side of said first portion, and a stationary portion including an outwardly extending annular flange at one edge of said ring, said stationary portion being joined to the constricted, flexible portion closest thereto, whereby vi-

bration of said bar causes movement of said first portion but not of said third portion.

7. A support for a vibrator bar having a peripheral, outwardly extending web, comprising a member having: a portion clamped to and movable with said bar, a stationary portion for supporting said bar, and a flexible portion joining said stationary and movable portions, whereby the former is caused to remain stationary during

movement of the latter, said stationary, flexible and movable portions being made of metal.

8. The support set forth in claim 7 in which said flexible portion is of constricted cross-section with respect to said stationary and movable portions.

No references cited.