

April 16, 1940.

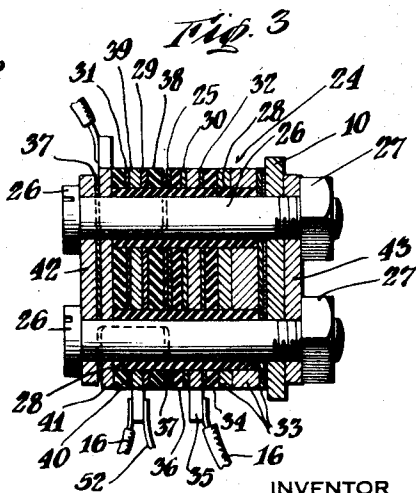
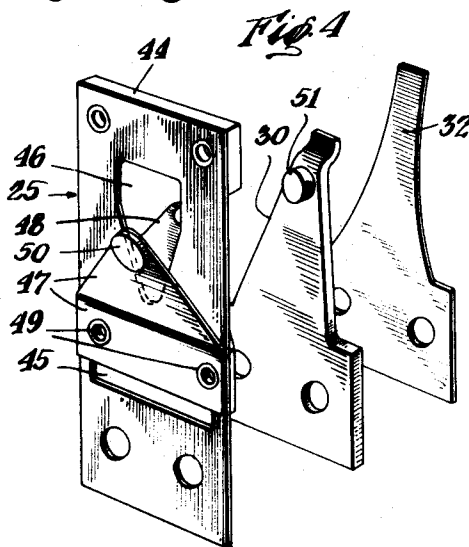
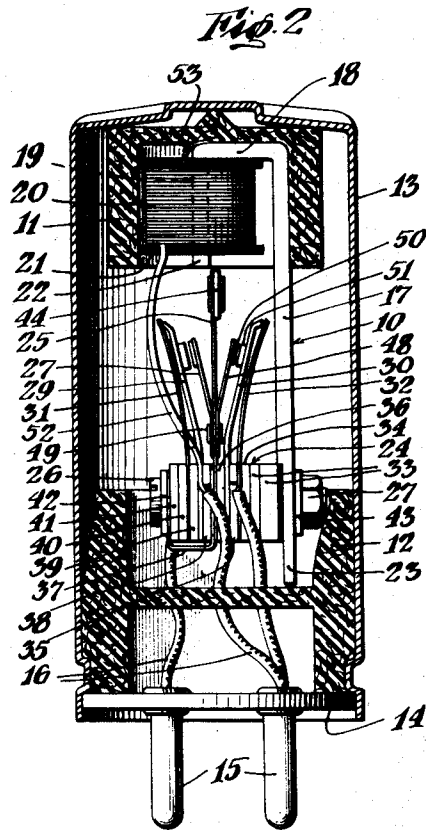
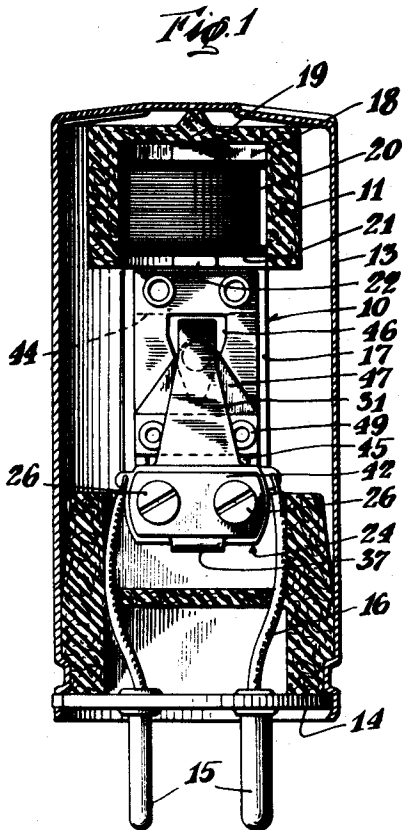
H. J. BROWN

2,197,607

VIBRATOR

Filed June 11, 1937

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

*Fig 5*

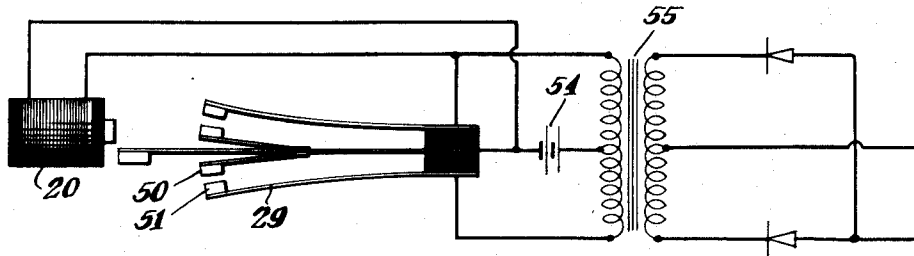


*Fig 6*

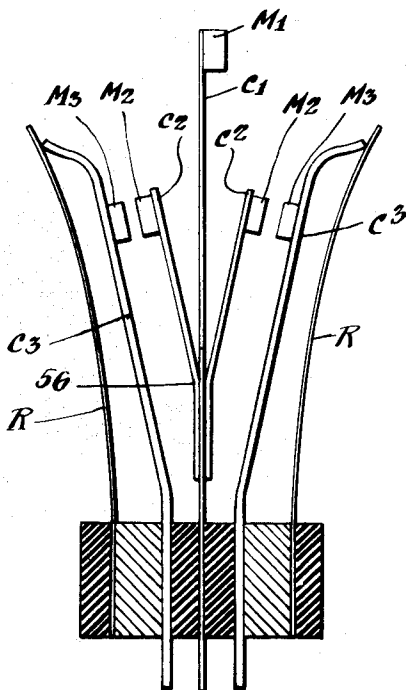
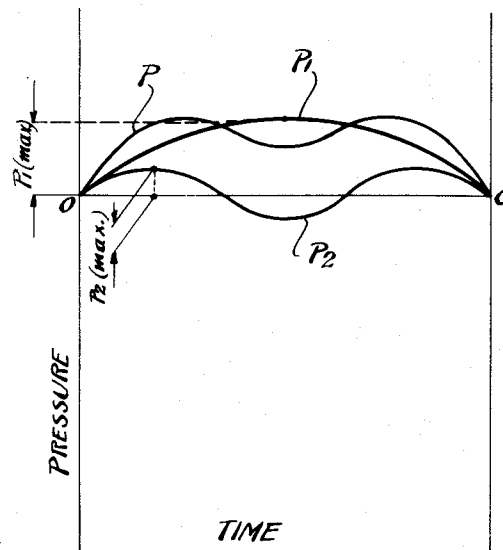


*Fig 7*



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## UNITED STATES PATENT OFFICE

2,197,607

## VIBRATOR

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Application June 11, 1937, Serial No. 147,692

11 Claims. (Cl. 200—90)

This invention relates to electromagnetic vibrators.

An object of the invention is to improve the structure and performance of electromagnetic vibratory interrupters used for interrupting electric currents.

Other objects of the invention will be apparent from the following description and accompanying drawings taken in connection with the appended claims.

The invention comprises the features of construction, combination of elements, arrangement of parts, and methods of manufacture and operation referred to above or which will be brought out and exemplified in the disclosure hereinafter set forth, including the illustrations in the drawings.

In the drawings:

Figure 1 is a longitudinal section through a vibrator embodying a preferred form of the present invention;

Figure 2 is a longitudinal section at right angles to the section of Figure 1;

Figure 3 is a cross-section through the vibrator "stack" assembly;

Figure 4 is an expanded perspective view of the reed and one of the "fixed" contacts of the vibrator;

Figure 5 is a circuit diagram of one type of circuit in which the structure of my invention may be used;

Figure 6 is a schematic diagram of the operating parts of the vibrator; and

Figure 7 is a graph illustrating contact pressures in the vibrator.

According to one aspect of the present invention the vibrator reed and co-operating contacts are improved in their structural proportions and in their dynamic relationships to improve the mechanical and electrical operation of the vibrator.

While a preferred embodiment of the invention is described herein, it is contemplated that considerable variation may be made in the method of procedure and the construction of parts without departing from the spirit of the invention. In the following description and in the claims, parts will be identified by specific names for convenience, but they are intended to be as generic in their application to similar parts as the art will permit.

Referring to the drawings the vibrator comprises a frame 10 resiliently supported and cushioned by recessed blocks 11 and of a yielding material such as sponge rubber, within metal

can 13. Can 13 is closed by an insulating disc 14 of Bakelite or the like upon which are mounted suitable connecting prongs 15 whereby the vibrator may be connected in a suitable circuit by inserting the prongs in co-operating jacks in a socket member. The prongs 15 are connected to the vibrator parts within the can by insulated conductor 16.

Frame 10 is preferably formed from a flat bar of a magnetic permeable material, such as iron, bent into what might be termed a rectangular hook shape so as to provide an elongated shank portion 17, a short transverse portion 18 at one end of the shank portion, and a short reverse portion 19 at the outer end of the transverse portion, the reverse portion 19 being substantially parallel to the shank portion 17. The shank portion 17 and transverse portion 18 are preferably, although not necessarily of equal width and thickness but the reverse portion 19 is preferably considerably narrower than the other portions so that the coil may be conveniently fitted over it. The single piece frame and core member adapts itself to precision manufacture, so that very little individual adjustment of the units is required.

Coil 20 is a winding of insulated wire on a bobbin 21. The central opening in form 21 is just sufficient in size to fit over reverse portion 19 of the frame with a snug fit so that the reverse portion comprises the core of the coil. If necessary the end or pole 22 of reverse portion 19 may be enlarged slightly after the coil form is in place by hammering or pressure to lock the coil form in place. With the coil mounted on the reverse portion in the manner described the magnetic variations caused by current variations in the coil are concentrated and made most effective at the pole of the core where they may be effective in controlling the reed.

The free end of shank portion 17 of the frame provides a flat surface 23 against which rests one end of a stack 24 of operating parts and spacers including an end of reed 25 and its co-operating contacts. The stack is held to the frame by the pair of stack screws 26 passing through the shank portion 17 of the frame and held by nuts 27.

Screws 26 are each surrounded by insulating sleeves 28 for part of their length. The stack assembly comprises the base ends of reed 25 and its co-operating contact arms 29 and 30 and their damping springs 31 and 32 clamped together with suitable metal and insulating spacers. Starting at face 23 of frame 10 the stack 24 comprises

metal spacers 33 of different thicknesses, insulating spacer 34, the base end of damping spring 32, metal spacer 35, the base of contact arm 30, insulating spacer 36, the base of reed 25, end of reed terminal strip 37, insulating spacer 38, base of contact arm 29, metal spacer 39, base of damping spring 31, insulating spacer 40, metal spacer 41, other end of reed terminal strip 37 and spring washer plate 42. Another spring washer plate 43 is positioned under nuts 27 against the outer face of frame 10.

Metal spacers 35, 39 and 41 are provided with terminal ears to which wires 16 are connected (by solder or otherwise) to provide terminal connections for contact arms 30 and 29 and reed 25, respectively. Terminal strip 37 forms a connecting loop between reed 25 and metal spacer 41. A wire 52 connects contact arm 29 to one end of electromagnet winding 20, the other end of winding 20 being grounded to frame 10 by conductor 53.

Reed 25 comprises a strip of spring metal, such as steel of uniform width. An armature bar 44 of magnetic permeable metal, such as iron, is riveted or eyeleted across the free end of the reed.

The reed is provided with two perforations or openings 45 and 46, opening 45 being a long narrow rectangular slot extending across the reed at the edge of the stack 24, the slot 45 extending to within a short distance of the reed edges so as to leave narrow connecting portions between the clamped end of the reed and its vibratory portion. Opening 46 comprises a centrally located tapered hole having its point in the vicinity of the center of the reed and its widest portion at the inside edge of armature 44.

A pair of reed contact arms 47 and 48 are eyeleted to the opposite sides of reed 25 by eyelets 49 passing through the reed assembly. The arms 47 and 48 each comprise a beveled plate of spring metal, such as steel. One of the beveled portions is rectangular in shape and riveted flat against the reed area immediately adjacent to slot 45. The other beveled portion is tapered to a rounded point. Contact discs 50 of tungsten or the like are brazed or welded to the outside faces of the contact arms at the rounded points.

Contact arms 29 and 30 are of metal stock and each comprise a rectangular base portion which is clamped in stack 24 and a tapered arm portion which is bent away from the reed at such an angle as to make the contact arm substantially parallel to the adjacent reed contact arm and a contact disc 51 is brazed or riveted to the arm at a point directly opposed to the corresponding reed contact 50. The ends of arms 29 and 30, beyond contacts 51, are bent away from the reed to provide rounded ends which rest against the ends of damping springs 31 and 32, respectively.

Damping springs 31 and 32 are made of relatively thin spring metal and each have a substantially rectangular base portion clamped in the stack 24 and a tapered arm portion, the end of which is biased so as to maintain a spring pressure against the end of its associated contact arm. This frictional contact between the spring and associated contact arm causes a critical damping of any harmonic vibrations set up in the contact arm when the contacts are closed and opened by the vibration of the reed.

Figure 5 shows one circuit in which the vibrator may be used. When connected in this circuit by prongs 15 a circuit will be closed from battery 54 through electromagnet winding 20 and half of the primary winding of transformer 55. Energization of the electromagnet will draw

the reed toward contact arm 29 closing contacts 50, 51 on the reed and arm 29 thereby short-circuiting the winding. The resulting deenergization of the electromagnet allows the reed to spring back to close the opposite contact pair and open the first pair and the cycle will thereafter be repeated causing pulsating currents in the halves of the transformer primary and alternating current in the secondary which may be rectified as shown.

It is also contemplated that the present general structure may be utilized with two pairs of contacts on each side of the reed in which case one pair may be used for interrupting primary current in the manner shown and the other pair connected in the secondary circuit to obtain a rectifying action in a well-known manner.

The dynamic relationships of the vibrator parts will be understood more clearly by reference to Figure 6. In this figure the reed, contact arm and damping spring assembly is shown diagrammatically. In this figure  $M_1$  represents the mass of the reed armature 44 plus the effective mass of the reed,  $M_2$  the mass of either of the reed contacts 50 plus the effective mass of a reed contact arm, and  $M_3$  the mass of either of the contact-arm contacts 51 plus the effective mass of the contact arm.  $C_1$  indicates the compliance of the reed in feet per pound applied at the center of gravity of  $M_1$  when the reed is clamped at point 56,  $C_2$  the compliance of the reed contact arm to force applied approximately at the center of gyration of  $M_2$  when the reed is clamped at point 56 and  $C_3$  the compliance of either of contact arms 29 and 30 plus their respective damping springs measured at the center of gyration of  $M_3$ .

During vibration of the reed in the manner previously described it will be seen that the contacts on one side of the reed are closed as the reed swings toward that side and the contacts remain closed for a short length of time (approximately for one-half cycle) during which the reed continues to the end of its swing and returns to center position. As the reed passes center position the contacts on the one side are opened and those on the other side (toward which the reed is swinging) are closed at a short interval later. The closed contacts remain closed for a short period of time and the cycle is repeated.

For the period during which one pair of contacts are closed the contact pressure  $P$  (= force with which the contacts are held together) varies from zero through one or more maximum values and back to zero. The contact pressure variation is a function of the masses of the reed armature and contacts and the compliances of the reed and contact springs. The pressure is equal to the sum of the reactive effects of the reed arm and the open reed contact arm or

$$P = P_1 + P_2$$

$P_1$  and  $P_2$  are of the form

$$P_1 = P_{1(\max)} \sin \omega_1 t$$

and

$$P_2 = P_{2(\max)} \sin \omega_2 t$$

where  $\omega_1$  is  $2\pi$  times the natural frequency  $f_1$  of the vibrator reed and  $\omega_2$  is  $2\pi$  times the natural frequency  $f_2$  of the reed contact arm while  $P_{1(\max)}$  and  $P_{2(\max)}$  are constants representing the maximum pressure effect components resulting from the reed reaction and the open reed contact arm reaction, respectively.

These natural frequencies will be determined by the mass and compliance of the vibratory members. From the well-known equations of simple harmonic motion it will be apparent that

$$\omega^2 = \frac{1}{\text{mass} \times \text{compliance}}$$

or applied to the present problem

$$\omega_1^2 = \frac{1}{M_1[C_1 + A^2(C_2 + C_3)]} \text{ (approx.)}$$

and

$$\omega_2^2 = \frac{1}{M_2 \left[ C_2 + \frac{C_1/A^2(C_2 + C_3)}{C_1/A^2 + C_2 + C_3} \right]} \text{ (approx.)}$$

where A is approximately the ratio of length of reed beyond point 56 to length of a reed contact arm. This reduced approximately to

$$\omega_2^2 = \frac{1}{2M_2C_2}$$

since  $C_1/A_2$  is greater than  $C_2$  and  $C_3$  less than  $C_2$ .

According to an important aspect of the present invention, whereby greater stability of operation and less contact wear is obtained, the vibrator parts are so designed that the natural frequency of vibration of the reed contact arms 47 and 48 satisfies the following equation:

$$\omega_2 = N\omega_1$$

where N is an odd integer, such as 1, 3, 5, etc. The above equation could also be written  $f_2 = Nf_1$  by dividing both sides by  $2\pi$ . Hence during a closed-contact interval substantially equal to  $\frac{1}{2}$  cycle of reed vibration the free reed contact arm will oscillate through an odd number of half cycles, i. e., through 0.5, 1.5, 2.5, 3.5 or more cycles of oscillation. The pressure effects  $P_1$  and  $P_2$  will then reach zero at the same time resulting in rapid, non-chattering opening of the contacts.

This relationship depends upon the relative masses of the armature 44 and contacts 50 and the relative stiffness (or compliance) of the reed and the contact springs. By a proper selection of the magnitude of these masses and stiffnesses the above relationship can be obtained. It will be apparent that the parts can be varied considerably and still satisfy the above equation, at least with sufficient approximation to attain, to a substantial degree, the advantage of the relationship. In this connection it is important that the contact spacing should be so adjusted by experiment or calculation as to achieve the fullest advantages of synchronization. By proper synchronization and spacing the contacts can be made to close with a minimum velocity resulting in a minimum of noise and wear. On opening the contacts will open with a clean, non-chattering motion.

In specific instances, therefore, the masses and stiffnesses of the parts may be selected to give the relation of approximately  $f_2 = 3f_1$  corresponding to 1.5 free contact oscillations in a closed contact interval and in other instances the relationship may be  $f_2 = f_1$ ;  $f_2 = 5f_1$ ; etc. There are, of course, practical limitations to the proportions which can be used. It is believed that the ones specifically mentioned above are most suitable for structures of the general design illustrated for present commercial practice. For the specific example given A may equal 2.

Referring to the contact pressure, which was stated to be of the form

$$P = P_1 + P_2 \\ = P_1(\max) \sin \omega_1 t + P_2(\max) \sin \omega_2 t$$

substituting  $N\omega_1$  for its equivalent  $\omega_2$  we obtain

$$P = P_1(\max) \sin \omega_1 t + P_2(\max) \sin N\omega_1 t$$

The meaning of this expression will be made clearer by reference to Figure 7. In this figure the curve  $P_1$  represents the variation in contact pressure component  $P_1$  during the period in which a given pair of the vibrator contacts are closed. It will be noted that this pressure component corresponds to the swing of the vibrator reed. This contact pressure due to the reed reaction increases from zero at the time the contacts close to a maximum  $P_1(\max)$  at the middle of the period of closure and then decreases again to zero following the form of a sine-wave.

The pressure component  $P_2$  due to the reaction of the free contact arm is represented by curve  $P_2$ . It will be noted that this pressure follows the vibration of the reed contact arm. The contact arm in this example, vibrates at about three times the frequency of the reed itself, that is  $f_2 = 3f_1$ , so that this pressure component first rises to a maximum  $P_2(\max)$  then falls off to zero. This component then becomes negative, or in other words comprises a force tending to separate the contacts as will be seen from the graph. The component again returns to zero and increases to a maximum in a positive direction and finally returns to zero at the same instant that the  $P_1$  component returns to zero.

As previously brought out the total contact pressure P comprises the sum of  $P_1$  and  $P_2$ . This total or resultant pressure is represented on the graph by curve P. It will be noted that the contact pressure, represented by curve P, increases rapidly from zero at the moment the contacts close to a maximum value after which there is a temporary but not serious decrease in pressure and then a second maximum, the pressure finally decreasing rapidly to zero at the end of the contact period.

The synchronized conditions just described correspond to the most desirable mode of contact operation. When the contacts are closed the pressure increases rapidly and remains high until the end of the contact period when the pressure falls off rapidly to zero, the contacts then separating rapidly so that arcing is minimized. It will be apparent that the rapid increase in contact pressure at the beginning and end of the contact period results from the fact that the reed and the reed contact arm are both swinging in the same direction at these times whereby both the reed and the contact arm contribute additively to the contact pressure increase or decrease. The reversal of pressure component  $P_2$  occurs when the pressure component  $P_1$  is at its maximum so that this reversal does not seriously reduce the resultant contact pressure as it would do if it occurred at another time in the contact cycle.

By the synchronization as described chatter is avoided and greater stability and less contact wear is achieved.

While the present invention as to its objects and advantages has been described herein as carried out in specific embodiment thereof, it is not desired to be limited thereby but it is

intended to cover the invention broadly within the spirit and scope of the appended claims.

What is claimed is:

1. A vibratory electric current interrupter device comprising an elongated reed having an armature at one end thereof, means clamping the opposite end of said reed, a pair of elongated spring arms secured, respectively, to the opposite faces of said reed near the clamped end thereof and extending away from said clamped end in spaced relation to said reed, a first electric contact on the free end of each of said spring arms, a second relatively fixed contact opposite each of said first contacts and adapted to co-operate with said first contacts to open and close alternate electric circuits responsive to vibration of said reed and spring arms, means for inducing vibratory oscillations of the free end of said reed and spring arms, the natural frequency of each of said spring arms being equal to  $Nx$  the natural frequency of said reed, where  $N$  is an odd integer.

2. A vibratory electric current interrupter device comprising an elongated reed having an armature at one end thereof, means clamping the opposite end of said reed, a pair of elongated spring arms secured, respectively, to the opposite faces of said reed near the clamped end thereof and extending away from said clamped end in spaced relation to said reed, a first electric contact on the free end of each of said spring arms, a second relatively fixed contact opposite each of said first contacts and adapted to co-operate with said first contacts to open and close alternate electric circuits responsive to vibration of said reed and spring arms, means for inducing vibratory oscillations of the free end of said reed and spring arms, the natural frequency of each of said spring arms being equal to  $Nx$  the natural frequency of said reed, where  $N$  is an odd integer selected from the integers 1, 3 and 5.

3. A vibratory interrupter device comprising a principal vibratory member and a pair of secondary vibratory members controlled by said principal member but having an individual vibratory motion, an electric contact mounted on each of said secondary vibratory members, relatively fixed contacts alternately co-operating with the respective vibratory contacts and means for vibrating said vibratory members, the natural frequency of each of said secondary vibratory members being equal to an odd integer  $x$  the natural frequency of said principal vibratory member.

4. A vibratory interrupter device comprising a principal vibratory member and a pair of secondary vibratory members controlled by said principal member but having an individual vibratory motion, an electric contact mounted on each of said secondary vibratory members, relatively fixed contacts alternately co-operating with the respective vibratory contacts and means for vibrating said vibratory members, the natural frequency of each of said secondary vibratory members being equal to 1, 3 or  $5x$  the natural frequency of said principal vibratory member.

5. A vibratory interrupter device comprising a frame, an electromagnet mounted thereon, an elongated metallic reed, means rigidly clamping one end of said reed to said frame, an armature of magnetic permeable material mounted on the free end of said reed, said free end and armature being within the sphere of magnetic

influence of said electromagnet whereby it is effective to vibrate the same, a pair of elongated spring arms secured, respectively, to opposite faces of said reed near the clamped end thereof and extending away from said clamped end in spaced relation to said reed, a first electric contact on the free end of each of said spring arms, a second contact mounted on said frame in co-operative relation with each of said first contacts whereby vibration of said reed by said electromagnet will vibrate said spring arms and alternately close the contact pairs on opposite sides of said reed, the natural frequency of each of said spring arms being equal to  $N$  times the natural frequency of said reed, where  $N$  is an odd integer.

6. A vibratory interrupter device comprising a frame, an electromagnet mounted thereon, an elongated metallic reed, means rigidly clamping one end of said reed to said frame, an armature of magnetic permeable material mounted on the free end of said reed, said free end and armature being within the sphere of magnetic influence of said electromagnet whereby it is effective to vibrate the same, a pair of elongated spring arms secured, respectively, to opposite faces of said reed near the clamped end thereof and extending away from said clamped end in spaced relation to said reed, a first electric contact on the free end of each of said spring arms, a second contact mounted on said frame in co-operative relation with each of said first contacts whereby vibration of said reed by said electromagnet will vibrate said spring arms and alternately close the contact pairs on opposite sides of said reed, the natural frequency of each of said spring arms being equal to  $Nx$  the natural frequency of said reed, where  $N$  is an odd integer equal to 1, 3 or 5.

7. A vibratory interrupter device comprising a frame, a vibratory member mounted thereon, a first contact on said vibratory member, an elongated contact spring arm clamped at one end to said frame and having the free end thereof disposed in co-operative relation to said vibratory contact whereby contact will be alternately made and broken between said vibratory contact and said contact spring responsive to vibration of said vibratory member, and damping means for said contact spring arm comprising a second spring arm of substantially the same length as said contact spring arm and clamped in spaced substantially parallel relation to said contact spring arm and extending parallel to said contact spring arm, the free ends of said two spring arms in the region of contact with said vibratory contact being held in frictional contact by said spring arms.

8. A vibratory electric current interrupter device comprising an elongated reed having an armature at one end thereof, means clamping the opposite end of said reed, a pair of elongated spring arms secured respectively, to opposite faces of said reed near the clamped end thereof and extending away from said clamped end in spaced relation to said reed, a first electric contact on the free end of each of said spring arms, a second relatively fixed contact opposite each of said first contacts adapted to close and open with said first contacts to control electric circuits responsive to vibration of said reed and spring arms, means for inducing vibratory oscillations of the free ends of said reed and spring arms, whereby said contact pairs will close together at alternate intervals, said vi-

bratory members producing a contact pressure  $P$  during said closed contact intervals which varies according to the equation:

$$P = P_1(\max) \sin \omega_1 t + P_2(\max) \sin N \omega_1 t$$

where  $P_1(\max)$  and  $P_2(\max)$  are constants,  $\omega_1$  is equal to  $2\pi$  times the reed frequency,  $N$  is an odd integer and  $t$  represents time measured from the instant when the contacts come together.

9. A vibratory interrupter device comprising a principal vibratory member and a pair of secondary vibratory members controlled by said principal member but having an individual vibratory motion, an electric contact mounted on each of said secondary vibratory members, relatively fixed contacts alternately co-operating with the respective vibratory contacts and means for vibrating said vibratory members, each of said secondary vibratory members being tuned to oscillate through 0.5, 1.5, 2.5 or 3.5 cycles during a closed contact interval for the other of said secondary vibratory members.

10. A vibratory electric current interrupter device comprising an elongated reed having an armature at one end thereof, means clamping the opposite end of said reed, a pair of elongated spring arms secured, respectively, to the opposite faces of said reed near the clamped end thereof and extending away from said clamped end in spaced relation to said reed, a first electric contact on the free end of each of

said spring arms, a second relatively fixed contact opposite each of said first contacts and adapted to co-operate with said first contacts to open and close alternate electric circuits responsive to vibration of said reed and spring arms, means for inducing vibratory oscillations of the free end of said reed and spring arms, each of said spring arms being tuned to vibrate through 0.5, 1.5, 2.5 or 3.5 cycles during a closed contact interval for the other of said spring arms.

11. A vibratory interrupter device comprising a frame, a vibratory member mounted thereon, a first contact on said vibratory member, an elongated contact spring arm clamped at one end to said frame and having the free end thereof disposed in co-operative relation to said vibratory contact whereby contact will be alternately made and broken between said vibratory contact and said contact spring arm responsive to vibration of said vibratory member, and damping means for said contact spring arm comprising a second spring arm of substantially the same length as said contact spring arm and clamped in spaced substantially parallel relation to said contact spring arm and extending parallel to said contact spring arm, the free ends of said two spring arms in the region of contact with said vibratory contact being held in frictional contact by said spring arms, said second spring being of greater flexibility than said contact spring arm.

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