

[54] **ELECTRIC SHAVER WITH
LONGITUDINALLY SPLIT CUTTER**

[75] Inventor: **Roger Paul Wellinger**, Neuchatel,
Switzerland

[73] Assignee: **The Gillette Company**, Boston,
Mass.

[22] Filed: **July 20, 1972**

[21] Appl. No.: **273,479**

[30] **Foreign Application Priority Data**

July 27, 1971	United Kingdom.....	35174/71
July 27, 1971	United Kingdom.....	35179/71
July 27, 1971	United Kingdom.....	35180/71

[52] U.S. Cl. **30/43.92, 30/346.51**

[51] Int. Cl. **B26b 19/04**

[58] Field of Search **30/43.8, 43.9, 43.91, 43.92,
30/346.51**

[56] **References Cited**

UNITED STATES PATENTS

2,202,203	5/1940	Hill	30/43.92
3,365,796	1/1968	Tozmie	30/43.92
3,504,433	4/1970	Futterer	30/43.92

FOREIGN PATENTS OR APPLICATIONS

449,153	3/1935	United Kingdom.....	30/43.92
1,045,853	12/1958	Germany	30/43.92

Primary Examiner—Al Lawrence Smith

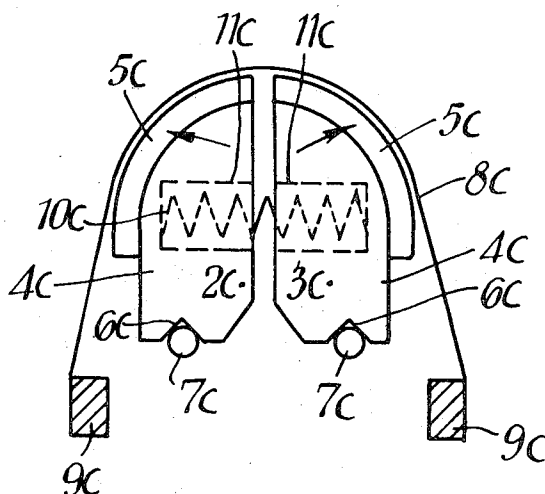
Assistant Examiner—Gary L. Smith

Attorney, Agent, or Firm—Flynn & Frishauf

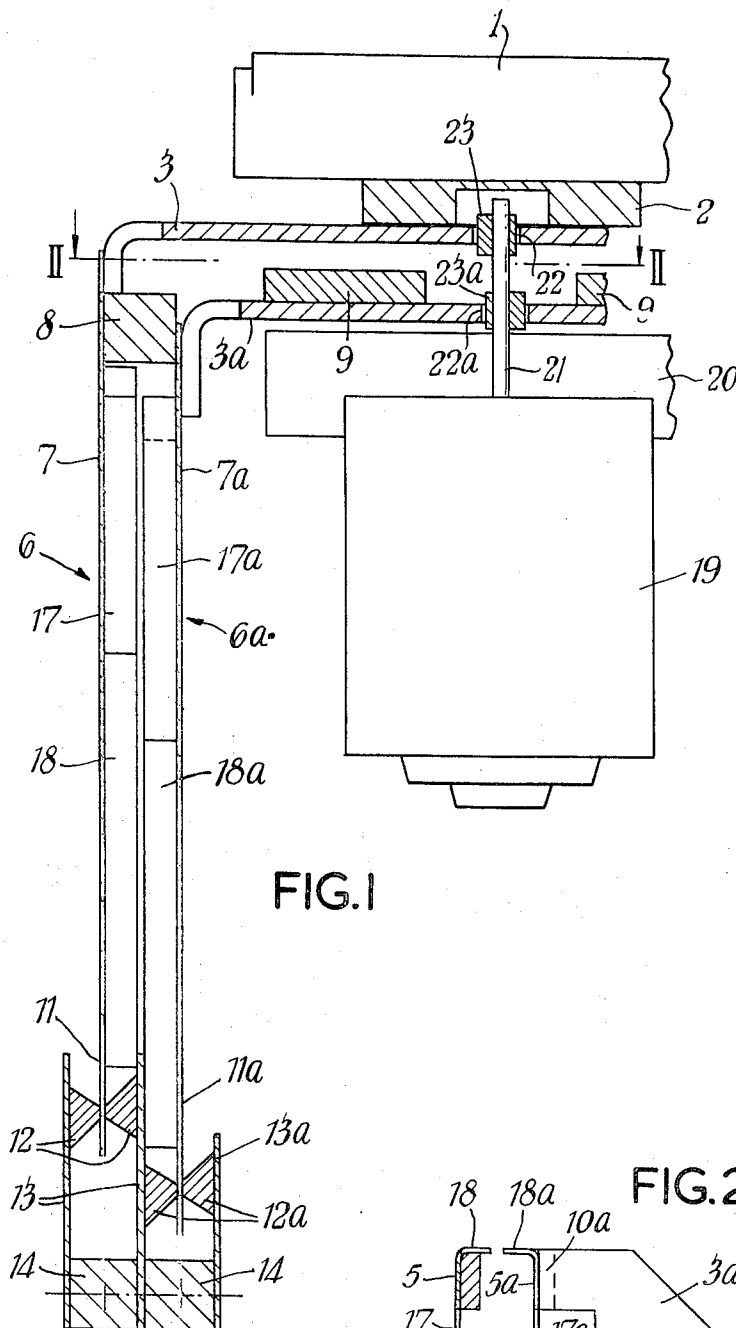
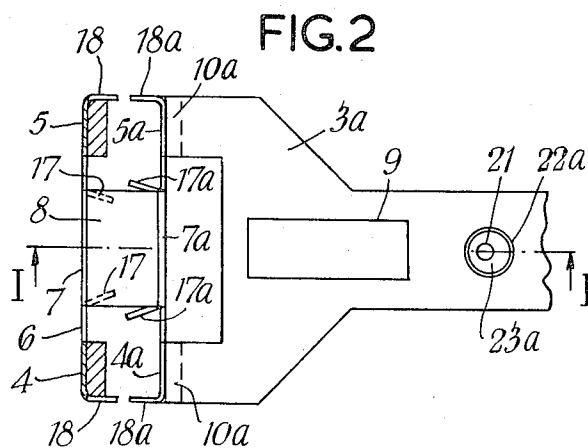
[57] **ABSTRACT**

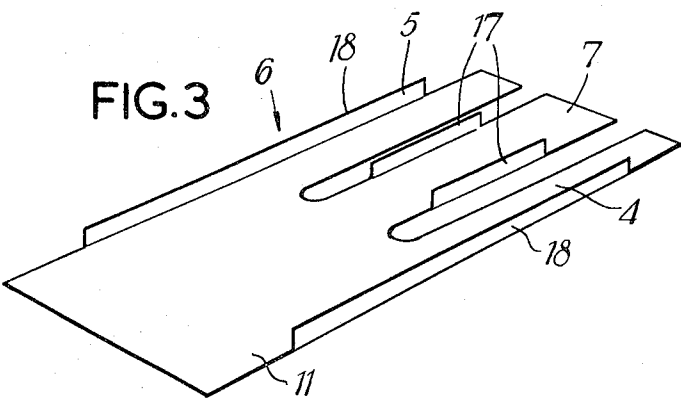
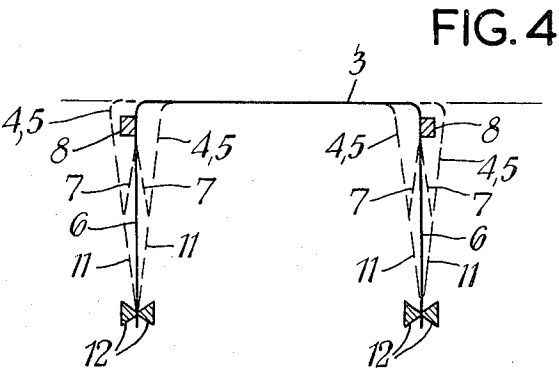
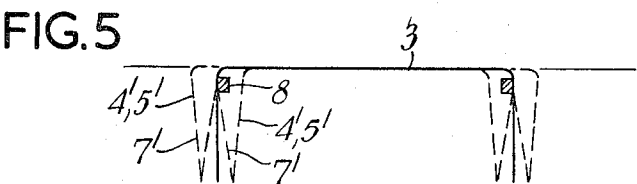
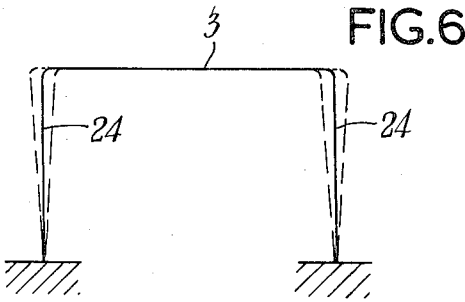
A battery powered electric shaver wherein a battery powered motor is adapted to drive two members in parallel reciprocation, respectively in antiphase, at least one of said members constituting a movable cutter, wherein the two members are each supported by a mounting incorporating a spring and the spring constants (K_1 , K_2) of the mounting springs are selected in relation to the masses (M_1 , M_2) of the respective members so that $\sqrt{K_1/M_1}$ is substantially equal to $\sqrt{K_2/M_2}$, whereby the two members have substantially the same natural frequency of reciprocation, and wherein the motor is operable under power supplied from the battery to drive said movable members at a frequency of reciprocation substantially equal to said natural frequency.

30 Claims, 12 Drawing Figures



SHEET 1 OF 4





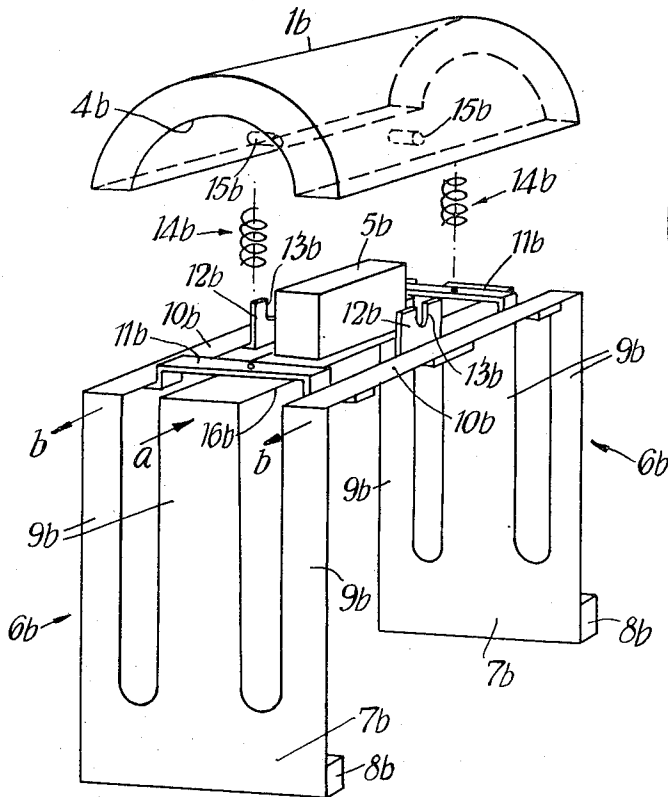


FIG. 7

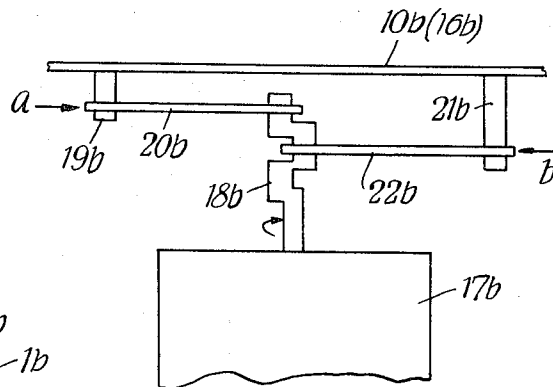


FIG. 8

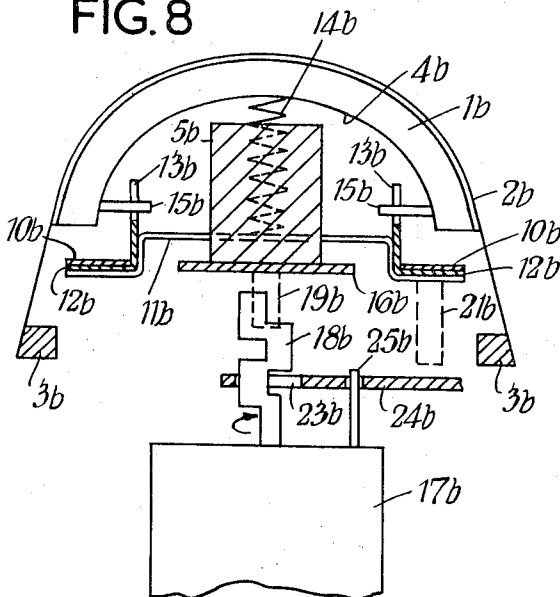


FIG. 9

FIG. 10

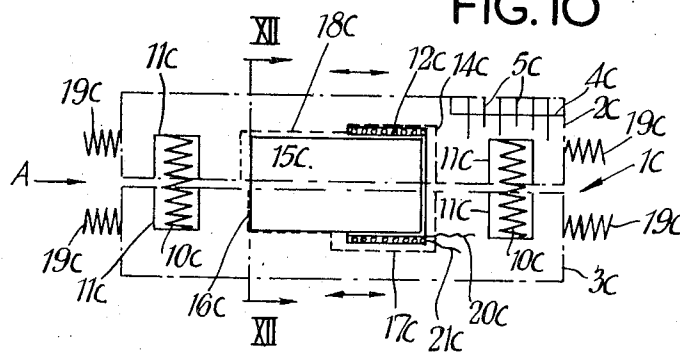


FIG. 11

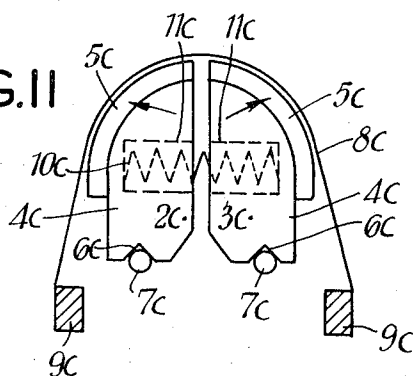
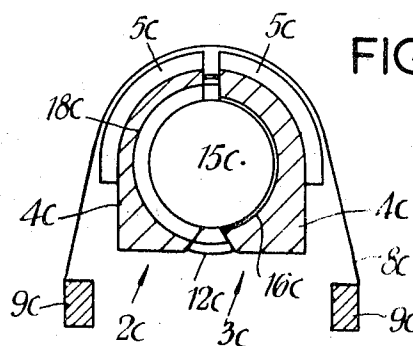


FIG. 12



ELECTRIC SHAVER WITH LONGITUDINALLY SPLIT CUTTER

This invention relates to battery powered electric shavers for shaving hair from human skin.

The power consumption of battery powered electric shavers is an important factor in that it determines the length of battery life, or recharging frequency and has an influence on the desired power and hence weight and bulk of the drive motor to be used. Vibration of the shaver body in use, which is in itself to be avoided for reasons of comfort and noise, can aggravate the power problem which is so important in a battery powered shaver.

According to the invention there is provided a battery powered electric shaver wherein a battery powered motor is adapted to drive two members in parallel reciprocation, respectively in antiphase, at least one of said members constituting a movable cutter, wherein the two members are each supported by a mounting incorporating a spring and the spring constants (K_1 , K_2) of the mounting springs are selected in relation to the masses (M_1 , M_2) of the respective members so that $\sqrt{K_1/M_1}$ is substantially equal to $\sqrt{K_2/M_2}$, whereby the two members have substantially the same natural frequency of reciprocation, and wherein the motor is operable under power supplied from the battery to drive said movable members at a frequency of reciprocation substantially equal to said natural frequency.

It will be understood that the respective spring mountings for the two movable members may form part of a single spring supporting structure, the spring constants K_1 and K_2 referring to the respective parts of said single structure which support the respective movable members.

A shaver in accordance with the invention has improved power consumption because of the resonant operation of its two operative members, each supported by a low-friction type of mounting, and the use of said two members operating in antiphase substantially reduces vibration.

The present invention is applicable to various types of cutting head, and in particular to the type of cutting head which consists of a stationary outer foil which is perforated and curved and an inner cutter which comprises a plurality of blades mounted on a carrier, the blades being profiled so as to match the curvature of the foil. The inner cutter is preferably oscillated along a substantially linear path parallel to the axis of curvature of the foil, but alternatively may be arcuately reciprocated about the axis of curvature of the foil.

However, a further aspect of this invention is that the two movable members of the dry shaver may comprise either the two parts of a split inner cutter, or a cutter and a counterweight in the vicinity of the cutter and oscillatable along a path substantially parallel with that of the cutter. Either arrangement substantially reduces vibration which is otherwise caused by the mass of a unitary oscillating cutter.

In the case of the counterweight, it is desirable for this to be mounted as close to the movable cutter as possible in order to minimize the small vibrational moment which occurs when their masses oscillate in antiphase along different axes.

Preferably, in the case of linear reciprocation, the spring supporting structure for the movable members (the cutter parts or the cutter and counterweight) in-

cludes two leaf springs spaced apart along the path of the cutter, cutter part, and/or counterweight respectively.

In a preferred construction using a pair of leaf springs for each movable member, each leaf spring has a plurality of adjacent arms, one or more arms having its end remote from its root secured to a fixed part of the shaver and the movable members (cutter, cutter part or counterweight) being mounted on the end or ends remote from the root or roots of the other arm or arms. Each leaf spring preferably has a stem which is restrained against reciprocation in the direction of reciprocation of the movable members.

In an alternative arrangement using a single pair of such leaf springs, one or more arms has its end remote from the root secured to one movable member and one or more other arms has its end remote from the root secured to the other movable member.

The exact nature of the battery powered driving means or power source used is not critical but it must be operable to drive the movable members at a frequency equal to or very close to their common resonant frequency.

Thus, a DC motor may be employed, fed from batteries contained in the shaver casing. A constant speed can be obtained from a DC motor relatively simply using a back-EMF bridge in association with a power control amplifier system. Alternatively, a servo-type system can be used in which a tachometer generator is driven by the motor and its output voltage, proportional to the motor speed is compared with a reference to provide an error signal for controlling the motor input current. When the motor is thus run at a constant speed it is necessary simply to arrange the resonant systems of the movable members of the shaver to match the speed of the motor. This may be done initially in an approximate fashion and a variable element may be included so that the motor speed can be varied over a range and can be manually adjusted within the range to achieve resonance of the movable members.

In order that the invention may be more clearly understood, some embodiments thereof will now be described, by way of example, with reference to the accompanying diagrammatic drawings, in which:

FIG. 1 is a cross-section, taken on line I—I in FIG. 2, of the main parts of one electric shaver according to the invention;

FIG. 2 is a cross-section taken on line II—II of FIG. 1;

FIG. 3 shows a resilient member in the form of a leaf spring from the shaver shown in FIGS. 1 and 2;

FIG. 4 illustrates the operation of a spring suspension system such as is shown in FIGS. 1 and 2;

FIG. 5 shows a modified form of spring suspension system;

FIG. 6 shows a further modified spring suspension system, which is particularly simple;

FIG. 7 is a partly exploded perspective view of a modified embodiment having a cutter and counterweight;

FIG. 8 is a transverse section through FIG. 7;

FIG. 9 is a side elevation of the driving means of FIG. 8;

FIG. 10 is a diagrammatic plan view of another embodiment employing a split cutter;

FIG. 11 is an end elevation taken in the direction of the arrow A in FIG. 10; and

FIG. 12 is a cross-section taken on the line 12—12 in FIG. 10.

Referring to FIG. 1, an inner movable cutter of the dry shaver is shown at 1. Of course, this will be associated with a stationary outer cutter, which may be a perforated foil, but since this is not important in this embodiment it is not illustrated, and neither is the surrounding casing with which the shaver would be normally provided.

The cutter 1 is to be oscillated along a substantially linear path in the direction of its length.

The cutter 1 is supported on a cutter supporting structure which includes a mounting block 2 on which the cutter 1 is secured, possibly with the interposition of some resilient means such as one or more springs, or rubber. The mounting block 2 is mounted directly on a bridge 3 which, at both ends, is bifurcated in the same manner as the bridge 3a, which is shown in FIG. 2 and which will be further referred to below. The two downwardly projecting portions at the left hand end of bridge 3 are securely fixed, for example by rivets, to the upper ends of the two outer arms 4 and 5 (see FIG. 3) of a resilient or spring member 6. The resilient member 6 takes the form of a leaf spring, as is shown in perspective in FIG. 3 but in longitudinal cross-section in FIG. 1. A transverse cross-section of resilient member 6 is seen in FIG. 2.

The resilient member 6 extends generally perpendicular to the path of oscillation of the cutter 1. A third and middle arm 7 of resilient member 6 is situated between the arms 4 and 5 and the upper end of arm 7 is secured, for example by rivets or screws, to a fixed part 8 of the shaver. The fixed part 8 may form part of a chassis carrying the working parts of the shaver within a suitable casing.

FIG. 1 shows in full only one side of the structure but this will in practice be symmetrical so that the left hand side of the structure, as shown in FIG. 1, would be duplicated in mirror image on the right hand side.

Thus, the cutter 1 is supported in the shaver by means of two resilient members 6, one at each end of the bridge 3.

A pair of counterweights 9 are fixedly mounted on the bridge 3a which is similar to, but shorter than, the bridge 3 and bridge 3a is supported at its ends by two resilient members 6a (of which only the left hand one is shown in FIG. 1) which are generally similar in form to the resilient member 6.

In FIGS. 1 and 2 the centre arm of resilient member 6a, numbered 7a, is shown secured to the fixed portion 8 of the shaver. The two outer arms 4a and 5a are secured to the downwardly projecting portions 10a at the end of the bridge 3a.

The resilient members 6 and 6a are of equal lengths but members 6 are set slightly higher than members 6a so that bridge 3 lies above bridge 3a. The counterweights 9 lie between the two bridges and are thus situated quite close to the movable cutter 1.

Referring to FIG. 3, the resilient member 6 extends away from the roots of the three arms 4, 5 and 7 in the opposite direction to said arms, the extension being indicated at 11. In FIG. 1 it can be seen that the extension 11 is restrained at a point remote from the roots of the arms by means of prism-shaped blocks 12 of deformable material, such as soft rubber, these blocks being mounted on plates 13 which in turn are fixed to a portion 14 of the shaver. A corresponding extension 11a

of resilient member 6a is similarly restrained by deformable blocks 12a of which one is mounted on the central plate 13 and the other on a further plate 13a. The lower end of the stem could alternatively be restrained by means of a transverse leaf spring connected thereto.

FIG. 4 shows diagrammatically the bridge 3 and its supporting structure including the two resilient members 6. The members 6 are shown in full lines in their central position, in which position they are illustrated in FIG. 1, and in broken lines in positions displaced to either side of the central position. As the bridge 3 is displaced to either side of its central position the fixed central arms 7 of members 6 are flexed out of the general plane of the members 6, whereas the outer arms 4 and 5 and the extensions 11 flex together, remaining in approximately the same plane.

The type of suspension shown in FIG. 4 can be arranged to produce a precisely linear path of displacement for the bridge 3. The fact that the portions 8 to which the central arms 7 are fixed may not be in the same plane as the bridge 3 may be compensated for by suitably selecting the relative flexibilities of the central arm 7 and the combination of the two outer arms 4 and 5.

As the bridge 3 is moved from side to side along its linear path the lower ends of the extension 11 move slightly in a direction perpendicular to the bridge 3. This movement is permitted by the deformability of the restraining blocks 12, while uncontrolled oscillation of the extensions 11 in the direction parallel to bridge 3 is prevented. By virtue of the resilience of the members 6 the cutter 1 bridge 3 and the members 6 themselves have a natural resonant frequency of vibration, with the cutter 1 oscillating along a linear path parallel with that of the bridge 3. The frequency will be determined by the mass (M_1) of the cutter 1 and bridge 3 and the stiffness (K_1) of the resilient members 6.

The members 6 may be made of thin sheet metal, for example copper beryllium or steel. To raise the natural resonant frequency in the embodiment described, the members 6 are stiffened and this prevents unwanted oscillations. This is achieved by means of upturned flanges 17 along the two side edges of the central arm 7 and further upturned flanges 18 which run along the edge of each of the outer arms 4 and 5 and continue along the opposite edges of the extension 11. Besides making the member 6 stiffer overall, the flanges 18 also ensure that the extension 11 and outer arms 4 and 5 flex together and that the central arm 7 flexes separately therefrom. This is significant because if the central arm 7 and the extension 11 were stiffened as a single unit, for example by means of a single central reinforcing member, they would stay substantially straight as bridge 3 oscillated from side to side because both the central arm 7 and the extension 11 are fixed or restrained. Then, the arms 4 and 5 would simply flex from side to side about approximately the centre of the member 6 and their upper ends would execute an arcuate motion having the small undesired component perpendicular to the bridge 3.

The bridge 3a supporting the counterweights 9 can oscillate in the same manner as bridge 3, as described with reference to FIG. 4, on its supporting resilient members 6a. The mass of the counterweights 9 is selected so that when they oscillate in antiphase to and parallel with the cutter 1 the resultant vibration is sub-

stantially zero. The natural frequency of the counterweights 9 on their supporting structure is tuned to be equal to that of the cutter 1 by suitably selecting or adjusting the stiffness constant (K_2) of the resilient members 6a in relation to the mass (M_2) of the counterweights 9 and bridge 3a, so that $\sqrt{K_2/M_2} = \sqrt{K_1/M_1}$, where K_1 is the stiffness constant of the resilient member 6 and M_1 the mass of the cutter 1 and bridge 3.

In the embodiment shown, the flanges 17a on member 6a extend slightly further upwards than the flanges 18a, the upper end of which is shown by broken lines in FIG. 1.

Referring again to FIG. 1 the driving means for the cutter 1 is shown in this embodiment as being an electric motor 19 mounted on a fixed portion 20 of the shaver. It is powered by batteries through a suitable control circuit (not shown) also housed within the casing of the shaver. The output shaft 21 of the motor passes through respective apertures 22 and 22a in the bridge 3 and the bridge 3a and located within these apertures and fixedly mounted on shaft 21 there are eccentric cams 23 and 23a respectively. The cams 23 and 23a are arranged to be 180° out of phase so that as the motor 19 rotates the bridges 3 and 3a are caused to oscillate along their linear paths in antiphase, thus producing the desired vibration-free operation.

In order to drive the cutter 1 and counterweights 9 at their natural resonance frequency ($\sqrt{K_1/M_1} = \sqrt{K_2/M_2}$) or a frequency very close thereto, the motor 19 must be controlled to the appropriate speed. Control circuitry of conventional kind suitable for achieving this with a battery powered DC motor has already been referred to. It will therefore not be described in detail herein.

FIG. 5 shows an alternative supporting structure which could be used for the bridge 3, and also for the bridge 3a. It can be seen that it corresponds with the supporting structure shown in the earlier Figures except that the extensions 11 of the resilient members are omitted. An exact linear path for bridge 3 is attainable with this structure but it has been found that in practice the lower end of the resilient member, at the roots of the outer arms 4 and 5 and the central arm 7, tends to develop a very high amplitude oscillation because it is unrestrained. The structure including an extension as shown in FIGS. 1 to 4 enables this oscillation to be restrained without interfering with the basic operation of this type of suspension system.

FIG. 6 shows a very simple type of suspension system using single resilient or spring members 24 which are fixed at their lower ends and carry the bridge 3 at their upper ends. This system oscillates in a similar way to that shown in FIG. 4 but the upper ends of members 24 have an arcuate motion so that the bridge 3 is given a slight component of motion perpendicular to its length, which in principle is not desirable, though in particular instances it may be tolerable because it is of small amplitude.

Using three-armed resilient members of the sort shown in FIG. 3, the two outer arms 4 and 5 could be secured to fixed portions of the shaver and the bridge 3 could be carried on the central arm 7. In that case, if stiffening of the resilient member is necessary, it would be done by reinforcement extending along the centre arm 7 and the extension 11 and separate reinforcement of the two arms 4 and 5 so that the latter two

arms could flex out of the general plane of the resilient element.

It will be apparent to one skilled in the art that the resilient or spring members could be formed from metal wire or from a suitable plastics material and also that they could be formed integrally with the bridges 3 and 3a.

The features of the constructions above described are highly significant in combination in a battery powered shaver, where the conservation of power is of prime importance. The use of resilient members for supporting the cutter and the counterweight produces a very low friction type of spring supporting structure for reducing power consumption. The use of a counterweight or counterweights oscillating in antiphase to the cutter results in low vibration when the shaver is operated, which also contributes to power saving. Most important, however, resonant operation of the cutter, and the counterweight is found very materially to reduce power consumption.

Resilient or spring members of the kind shown in FIGS. 1 to 5 enable the movement of the cutter, and of the counterweights when present, to be made very precisely linear, and the constructions shown in FIGS. 1 to 4 substantially eliminate the unwanted vibrations which may occur in the structure shown in FIG. 5.

A feature of resilient supporting members such as have been described is that they perform the combined functions of supporting, guiding along a substantially linear path, and applying a resilient bias towards the rest position.

Referring to the modified embodiment of FIGS. 7 and 8, an inner cutter is schematically shown at 1b. Cutters of this general form are known and usually include a plurality of blades extending transversely of the axis of the cutter and having curved outer cutting edges. In FIG. 8 a curved outer cutter is shown in the form of a foil which is perforated and the curvature of which matches that of the inner cutter 1b. The lateral edges of the foil 2b are secured to fixed parts 3b of the shaver.

The underside of the cutter 1b has the form of a recess 4b within which the greater part of a counterweight 5b is located.

The movable cutter 1b and the counterweight 5b are supported so as to be oscillatable along substantially parallel substantially linear paths in antiphase, by means of two resilient members 6b which extend substantially perpendicular to the paths of the cutter and counterweight and are spaced apart in the direction of said paths.

Each resilient member 6b has a root end 7b which is secured in a suitable manner to a fixed part 8b of the shaver. From the root end 7b three substantially parallel arms 9b extend towards the shaver head. The resilient members 6b preferably each consist of a metal leaf spring, but may be made from plastic, or may be made by bending spring wire into a form providing the three arms 9b.

The corresponding outer arms 9b of the two resilient members are joined together by longitudinal members 10b and the two members 10b are respectively linked transversely by means of bridge pieces 11b near each end thereof. Upstanding lugs 12b are provided on the longitudinal members 10b and each of the lugs has an upwardly opened slot 13b therein.

The cutter **1b** is supported on the four outer arms **9b** of the resilient members **6b** by means of suitable spring mountings **14b** which are indicated in a schematic manner. Various suitable types of mounting are known. The spring mountings **14b** secure the cutter **1b** to the two bridge pieces **11b** and bias it away from the bridge pieces **11b** so that it is pressed against the inside of the curved foil **2b**.

Pegs **15b** extending from opposite sides of the cutter **1b** into the recess **4b** engage in the slots **13b** in lugs **12b**. Longitudinal oscillation is transmitted to the cutter **1b** by means of this engagement, as will become apparent.

The counterweight **5b** is mounted on a longitudinal member **16b** which joins the two middle arms **9b** of the resilient members **6b**.

Thus, because of the resilience of the arms **9b**, which enables them to flex in both directions from their normal position, the counterweight **5b** and the cutter **1b** can be made to oscillate in antiphase along substantially parallel substantially linear paths, as indicated by the arrows *a* and *b* respectively.

Referring to FIGS. 8 and 9, the prime mover of the razor is a battery powered motor **17b** which drives a three-throw crank shaft **18b**. The upper two throws of the crank shaft **18b** are at 180° to each other. The upper throw is connected to a pin **19b** on the longitudinal member **16b** which carries the counterweight **5b** by means of a connecting rod **20b** (see FIG. 9). The middle throw is connected to a pin **21b** on one of the longitudinal members **10b** carrying the movable cutter **1b** by means of a connecting rod **22b**. For the sake of clarity the pins **19b** and **21b** are shown in broken lines at FIG. 8 and the connecting rods are not shown in that Figure. None of the driving mechanism is shown in FIG. 7, again for the sake of clarity.

Thus, when the electric motor **17b** is energised from the battery the crank shaft **18b** rotates and, because the upper two throws of the crank shaft are 180° out of phase the longitudinal members **10b** and the longitudinal members **16b** are driven to and fro in antiphase with each other, and consequently the cutter **1b** and counterweight **5b** are also driven along their substantially linear paths in antiphase.

The lowest throw of crank shaft **18b** engages in a slot **23b** (see FIG. 8) in a lever **24b** which is pivoted on a pivot pin **25b**, so that the lever **24b** undergoes a rotary oscillation about the pin **25b** when the motor **17b** is actuated. The free end of lever **24b** can be used to drive a clipper-type long hair cutter or trimmer which may be attached to the side of the razor. Various types of long hair cutters or trimmers are known which require a to and fro movement to drive them and any of these types may be used.

The mass of the counterweight **5b** is selected such that as it oscillates in antiphase with the movable cutter linear vibrations are compensated for as completely as possible. As has been mentioned, it is also desirable for the centre of mass of the counterweight **5b** to move on the same axis as the centre of mass of the movable cutter **1b**. This may require the counterweight to be more, or less, recessed into the cutter **1b** than is illustrated in FIG. 8. Its centre of mass can be lowered, as viewed in the Figure, by making the counterweight **5b** lower and flatter and its centre of mass can be raised, as viewed in FIG. 8, by making the counterweight of a shape which fits more closely within the upper part of the recess **4b** and, if necessary, supporting the counterweight

on a support member intermediate the counterweight and the longitudinal member **16b**.

In order to achieve resonant operation, the resonant frequencies of the two oscillating systems are predetermined by suitably relating the stiffnesses (K_1 and K_2) of the middle and outer arms **9b** in relation to the masses M_1 and M_2 of the cutter and the counterweight. The stiffnesses of the arms will depend on their widths and thicknesses.

The battery powered shaver is arranged to drive the cutter and counterweight substantially at their common resonant frequency in the manner described with respect to the previous embodiment.

The resilient members **6b** and the longitudinal members **10b** and **16b** which join them together may be formed integrally from a single piece of metal or plastics material.

Although in the embodiment shown each of the resilient members **6b** has three arms it is possible for these to have only two arms each, the corresponding arms of the two resilient members being joined by respective longitudinal members. The movable cutter **1b** could then be mounted in some suitable manner on one of the longitudinal members and the counterweight **5b** on the other.

By using one or more counterweights recessed into a movable cutter and oscillating in antiphase therewith, as referred to herein, a compact and balanced shave system is obtained. The described supporting system using resilient members extending approximately perpendicular to the paths of the oscillating members makes for very low friction and hence reduces load on the batteries. The three-armed type of resilient member which has been described is a particularly convenient way of arranging this form of support for two systems oscillating in antiphase.

Referring to FIGS. 10, 11 and 12 of the drawings, in a further embodiment, one form of inner movable cutter is indicated generally at **1c** in chain lines in FIG. 10 and consists of two parts **2c** and **3c** which extend longitudinally and parallel to each other. Each of the cutter parts **2c** and **3c** consists of a base block **4c** which may, for example, be made from moulded nylon and which carries a plurality of transversely extending parallel cutter blades **5c** having cutting edges which in the transverse direction are of convex form. They may be in the form of arcs of a circle. Many different forms of construction for semi-cylindrical or approximately semi-cylindrical movable inner cutters are known and it is to be expected that similar forms of construction could be applied to a two-part movable inner cutter such as is being described.

Referring to FIG. 11 the base blocks **4c** are formed on their undersides with notches **6c** by means of which the two cutter parts **2c** and **3c** are supported on longitudinally extending low-friction support rods **7c**. The rods **7c** may, for example, be made of nylon or polished metal. They are mounted on a suitable fixed part (not shown) of the shaver. The rods **7c** and the notches **6c** need not extend for the whole length of the shaver head. Each of the base blocks **4c** may be formed with a single notch **6c** at each end which rests on a corresponding short section of rod **7c**.

In FIGS. 11 and 12 an outer perforated cutter foil **8c** is shown which is arched over the two cutter parts **2c** and **3c** and secured at its lateral edges to fixed parts **9c** of the shaver.

Means in the form of two coil springs 10c, in compression, operate to continually bias the two cutter parts 2c and 3c away from each other so that the cutting edges of the blades 5c are pressed into contact with the underside of the foil 8c, as indicated by the arrows in FIG. 11. The springs 10c are each housed in a pair of bores 11c which extend transversely into each of the base blocks 4c and the ends of the springs bear against the ends of the bores 11c.

Referring to FIGS. 10 and 12, the driving means for the cutter parts 2c and 3c is a vibratory motor comprising one movable system in the form of a coil 12c which forms a unitary structure with the movable cutter 2c by virtue of being fitted and secured (e.g., by a suitable adhesive) into a semi-cylindrical recess 14c therein, which recess is shown in broken lines in FIG. 10. Another movable system of the linear motor, in the form of a permanent magnet 15c coaxial with coil 12c, forms a unitary structure with the other cutter part 3c, being similarly secured in a semi-cylindrical recess 16c therein.

Thus, approximately half of coil 12c and of magnet 15c is recessed and secured into the respective one of cutter parts 2c and 3c, and the other approximately half of each of these reactive systems of the motor extends into a semicylindrical recess, 17c and 18c respectively, in the opposite cutter part. Lateral clearance is allowed between the cylindrical walls of the recesses 17c and 18c and the motor reactive system which oscillates relative thereto, and recesses 14c, 17c and 18c have sufficient clearance at their ends to accommodate the amplitude of oscillation. This clearance could be limited so as to limit the amplitude of oscillation of the two cutter parts.

Biasing springs 19c act between opposite ends of the cutter parts 2c and 3c and suitable fixed parts (not shown) of the shaver to impart a common resonant frequency to the moving parts, this frequency being dependent on the masses (M_1 , M_2) of the moving parts in relation to the spring constants (K_1 , K_2) of the springs. It will be appreciated that a resonance frequency may be provided in other ways, for example, a spring coupling between the two movable cutters or between the two reactive systems of the linear motor.

It can be seen that the illustrated arrangement is very compact in that the whole of the linear motor is housed within the recesses in the blade carriers and these are entirely within the head of the shaver. Both the magnet 15c and the coil 12c are shown as being cylindrical, but they could be given other cross-sectional shapes so as to fit more compactly into the particular shape of shaver head used in any particular shaver.

To operate the shaver the coil 12c is fed from a battery with an alternating or pulsed voltage via leads 20c and 21c. An alternating current will produce alternate repulsion and attraction between the two reactive systems of the motor i.e., coil 12c and magnet 15c and hence vibration in antiphase of the two movable cutter parts 2c and 3c. The same effect will be caused by a pulsed voltage except that this will produce a driving impulse only once in each cycle and always in the same direction.

Resonant operation is achieved by matching the resonant frequency to that of the driving voltage, or vice versa. Resonant operation produces a considerable decrease in power consumption.

The masses of the two oscillating systems are ideally made such that when they are vibrating in antiphase the resultant vibration is zero. A small vibrational moment will still exist if the centres of gravity of the two systems do not move along the same axis.

The addition of counterweights may be desirable if the masses of the operative parts of the two vibratory systems cannot otherwise be easily matched.

Although the described embodiment includes only two movable inner cutters, more than two could be provided. For example, if three parallel cutters were used one reactive system could be associated with the central one and the other reactive system with the other two. Using four cutters, two of them could be associated with each of the reactive systems.

Although movable as a unit in operation, each reactive system and its associated cutter may be detachable from each other for replacement or cleaning purposes.

Although not illustrated and specifically described, it will be obvious that the invention is also applicable to an electric razor having an inner cutter reciprocating arcuately about the axis of a curved outer foil. The arcuately reciprocating cutter may be split in a plane transverse to the axis of arcuate reciprocation, the two cutter parts reciprocating in antiphase, or a counterweight may be driven in arcuate reciprocation in antiphase to the reciprocation of the cutter and about the same axis of reciprocation. The two movable members thus defined can be supported by mountings each including a spring providing torsion about the axis of arcuate reciprocation. The torsional spring constants (K_1 , K_2) of the springs are chosen in relation to the masses (M_1 , M_2) of the two movable members so that $\sqrt{K_1/M_1}$ is substantially equal to $\sqrt{K_2/M_2}$, to give the members the same natural frequency of arcuate reciprocation, and the battery powered drive motor is operated at this common natural frequency to achieve resonant operation.

Furthermore, the invention is also applicable to battery powered electric razors which are not of the foil type, but have two cooperating cutter heads driven in antiphase to provide a shearing action.

I claim:

1. An electric shaver comprising:

at least two movably mounted members having respective masses (M_1 , M_2), at least one of said members comprising a movable inner cutter cooperating with an outer foil and the other of said members comprising a counterweight, said counterweight being at least partly recessed into said movable inner cutter;

driven means including a motor coupled to and reciprocatingly driving said two members respectively in antiphase;

support means including mountings coupled to and resiliently supporting each of said at least two members, each mounting including a spring, the spring constants (K_1 , K_2) of the mounting springs being selected in relation to the masses (M_1 , M_2) of the respective members so that $\sqrt{K_1/M_1}$ is substantially equal to $\sqrt{K_2/M_2}$, so that at least two members have substantially the same natural frequency of reciprocation and the counterweight compensates for vibrations;

said motor being operable under power to drive both of said movable members substantially continu-

ously at a frequency of reciprocation substantially equal to said natural frequency.

2. An electric shaver according to claim 1, wherein said mountings support both of said members for linear reciprocation.

3. An electric shaver according to claim 1, wherein said inner cutter is split longitudinally of the direction of linear reciprocation.

4. An electric shaver according to claim 1, wherein the centre of mass of the counterweight reciprocates on a path substantially collinear with the path of reciprocation of the centre of mass of the cutter.

5. An electric shaver according to claim 1, wherein the motor is a vibratory battery operated motor having at least one reactive system including a permanent magnet and a cooperating coil connected through a control circuit to the battery, the magnet being mounted on one member and the coil on the other.

6. An electric according to claim 5, including one or more reactive systems wherein coils are mounted on the movable members and the magnet or magnets on a fixed part of the shaver.

7. An electric shaver according to claim 5, wherein two parts of the one or more reactive systems are respectively housed, at least in part, within the two movable members.

8. An electric shaver according to claim 1, wherein the motor has a rotary output shaft for driving a crank shaft having a pair of crank throws relatively positioned to drive said at least two movable members in anti-phase.

9. An electric shaver according to claim 1, wherein the mounting for each member comprises a pair of leaf springs having at least two arms projecting from a common root, at least one arm being secured at its free end to the respective member and at least one arm being secured at its free end to a fixed part of the shaver.

10. An electric shaver according to claim 1, wherein the mounting for the at least two members comprises a single pair of leaf springs having at least two arms projecting from a common root, at least one arm being secured at its free end to one member and at least one other arm being secured at its free end to another member.

11. An electric shaver according to claim 1, wherein said motor is a battery powered motor.

12. An electric shaver according to claim 1, wherein said at least two members are arranged to be driven in parallel reciprocation.

13. An electric shaver according to claim 12, wherein said at least two members are further arranged to be driven in non-aligned paths.

14. An electric shaver comprising:

at least two movably mounted members having respective masses (M_1, M_2), at least one of said members comprising a movable inner cutter cooperating with an outer foil and the other of said members comprising a counterweight;

drive means including a motor coupled to and reciprocatingly driving said two members respectively in antiphase;

support means including mountings coupled to and resiliently supporting each of said at least two members, each mounting including a spring, the spring constants (K_1, K_2) of the mounting springs being selected in relation to the masses (M_1, M_2) of the respective members so that $\sqrt{K_1/M_1}$ is sub-

stantially equal to $\sqrt{K_2/M_2}$, so that the at least two members have substantially the same natural frequency of reciprocation and the counterweight compensates for vibrations;

5 said motor being operable under power to drive both of said movable members substantially continuously at a frequency of reciprocation substantially equal to said natural frequency, said motor comprising a vibratory battery operated motor having at least one reactive system including a permanent magnet and a cooperating coil connected through a control circuit to the battery, the magnet being mounted on one member and the coil on the other.

15. An electric shaver according to claim 14 wherein said cutter and counterweight are mounted for linear reciprocation.

16. An electric shaver according to claim 14, including one or more reactive systems wherein coils are mounted on the movable members and the magnet or magnets on a fixed part of the shaver.

17. An electric shaver according to claim 14, wherein two parts of the one or more reactive systems are respectively housed, at least in part, within the two movable members.

18. An electric shaver according to claim 14, wherein the motor has a rotary output shaft for driving a crank shaft having a pair of crank throws relatively positioned to drive said at least two movable members in anti-phase.

19. An electric shaver according to claim 14, wherein the mounting for each member comprises a pair of leaf springs having at least two arms projecting from a common root, at least one arm being secured at its free end to the respective member and at least one arm being secured at its free end to a fixed part of the shaver.

20. An electric shaver according to claim 14, wherein the mounting for the at least two members comprises a single pair of leaf springs having at least two arms projecting from a common root, at least one arm being secured at its free end to one member and at least one other arm being secured at its free end to another member.

21. An electric shaver according to claim 14, wherein said inner cutter is split longitudinally of the direction of linear reciprocation.

22. An electric shaver comprising:

at least two movably mounted members having respective masses (M_1, M_2), at least one of said members comprising a movable inner cutter cooperating with an outer foil and the other of said members comprising a counterweight;

drive means including a motor coupled to and reciprocatingly driving said two members respectively in antiphase;

support means including mountings coupled to and resiliently supporting each of said at least two members, each mounting including a spring, the spring constants (K_1, K_2) of the mounting springs being selected in relation to the masses (M_1, M_2) of the respective members so that $\sqrt{K_1/M_1}$ is substantially equal to $\sqrt{K_2/M_2}$, so that the at least two members have substantially the same natural frequency of reciprocation and the counterweight compensates for vibrations, said cutter and counterweight being supported and driven such that the centre of mass of the counterweight reciprocates

13

on a path substantially collinear with the path of reciprocation of the centre of mass of the cutter; said motor being operable under power to drive both of said movable members substantially continuously at a frequency of reciprocation substantially equal to said natural frequency.

23. An electric shaver according to claim 22 wherein said cutter and counterweight are mounted for linear reciprocation.

24. An electric shaver according to claim 22 wherein said inner cutter is split longitudinally of the direction of linear reciprocation.

25. An electric shaver according to claim 22, wherein the motor is a vibratory battery operated motor having at least one reactive system including a permanent magnet and a cooperating coil connected through a control circuit to the battery, the magnet being mounted on one member and the coil on the other.

26. An electric shaver according to claim 25, including one or more reactive systems wherein coils are mounted on the movable members and the magnet or magnets on a fixed part of the shaver.

27. An electric shaver according to claim 25, wherein

14

two parts of the one or more reactive systems are respectively housed, at least in part, within the two movable members.

28. An electric shaver according to claim 25, wherein the motor has a rotary output shaft for driving a crank shaft having a pair of crank throws relatively positioned to drive said at least two movable members in anti-phase.

29. An electric shaver according to claim 25, wherein the mounting for each member comprises a pair of leaf springs having at least two arms projecting from a common root, at least one arm being secured at its free end to the respective member and at least one arm being secured at its free end to a fixed part of the shaver.

30. An electric shaver according to claim 22, wherein the mounting for the at least two members comprises a single pair of leaf springs having at least two arms projecting from a common root, at least one arm being secured at its free end to one member and at least one other arm being secured at its free end to another member.

* * * * *

25

30

35

40

45

50

55

60

65