May 5, 1970 B. R. MEAD **3,509,626**

ELECTROMECHANICAL RAZOR OPERABLE AT HIGH FREQUENCIES

Filed March 11, 1968 3 Sheets-Sheet 1

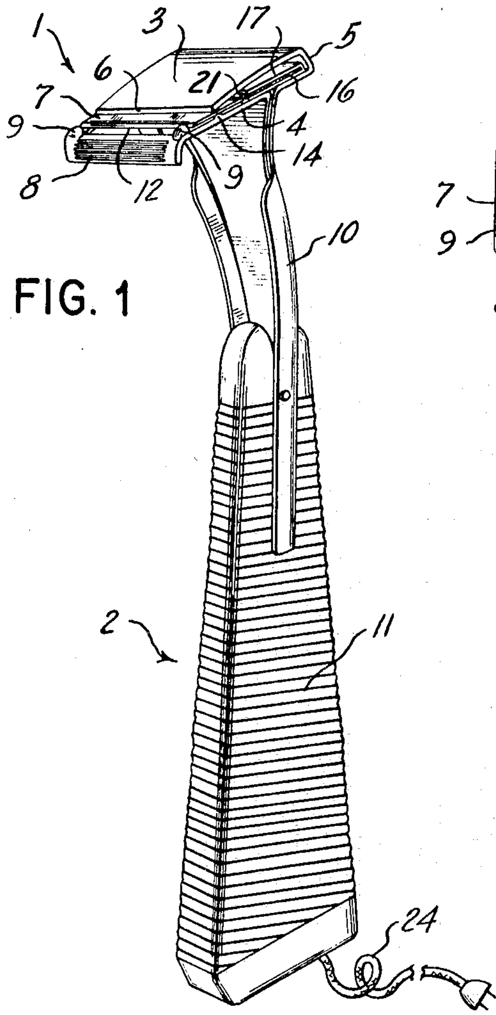


FIG. 1

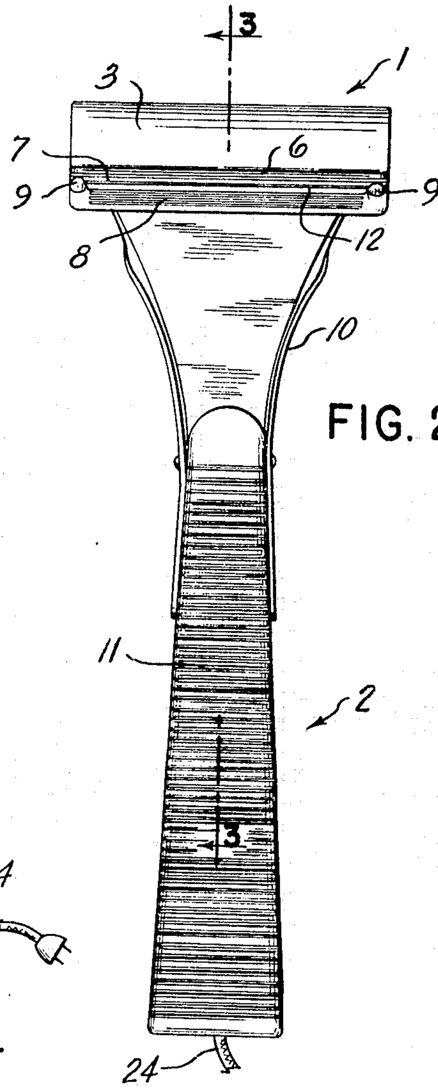
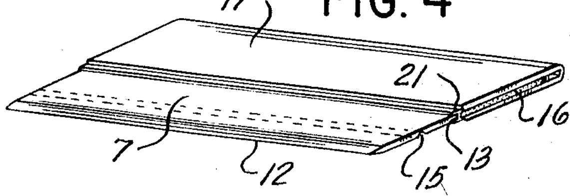


FIG. 2

FIG. 4



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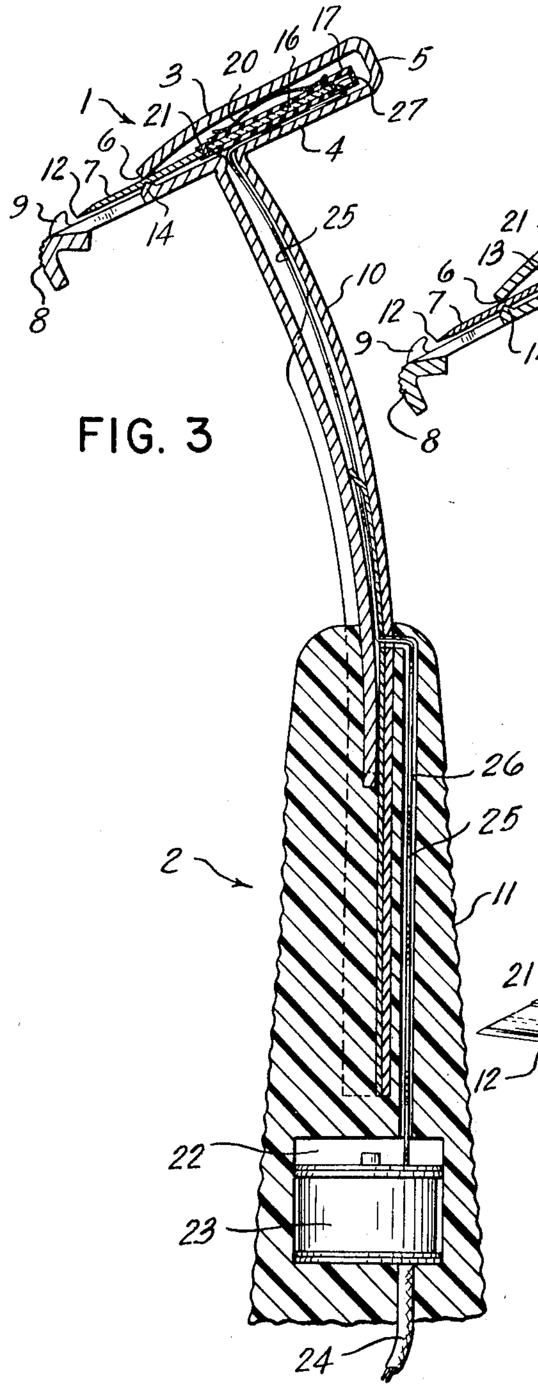


FIG. 3

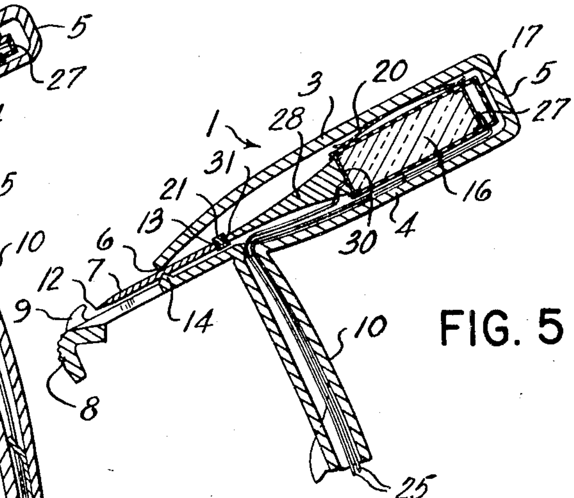
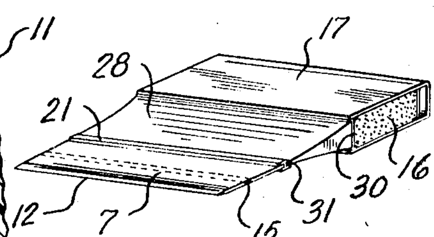


FIG. 5

FIG. 6



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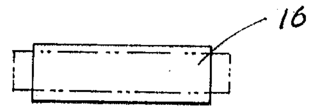

FIG. 8

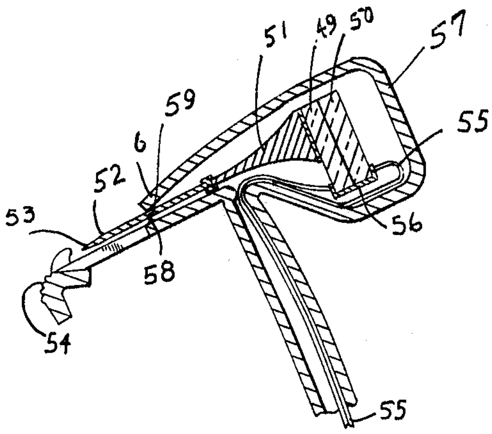

FIG. 7

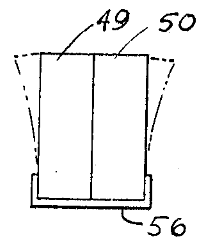

FIG. 9

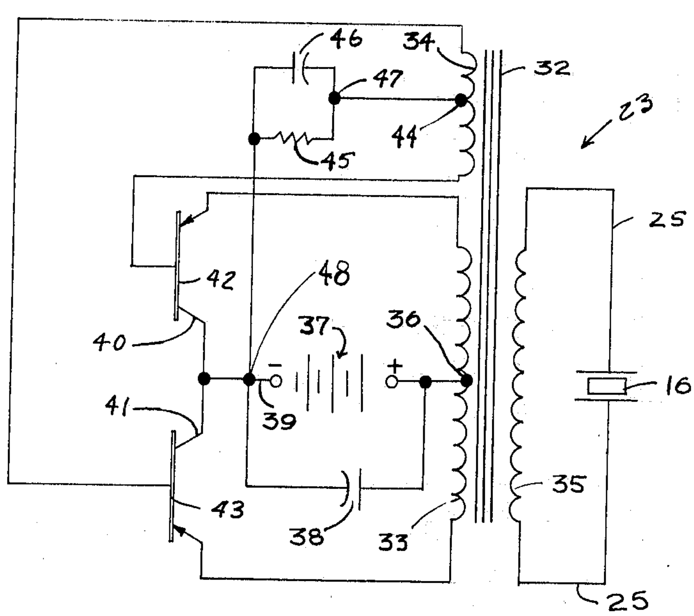

FIG. 10

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ELECTROMECHANICAL RAZOR OPERABLE AT HIGH FREQUENCIES

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Continuation-in-part of application Ser. No. 431,606, Feb. 10, 1965. This application Mar. 11, 1968, Ser. No. 711,954

Int. Cl. B26b 21/00

U.S. Cl. 30—45 11 Claims

ABSTRACT OF THE DISCLOSURE

An electromechanical razor in which transducer means operable at an ultrasonic frequency, is mechanically coupled to one end of a razor or like blade held in razor head means, and wherein the vibrational energy of the transducer causes ultrasonic vibrations in the cutting blade. In a preferred embodiment, the output of an electronic inverter is fed to a piezoelectric crystal held against a back edge of the blade, and vibrational energy from the crystal is fed to the blade, preferably in resonance with a natural or imposed frequency thereof, causing the blade, or portions thereof, to vibrate at a frequency of at least about 100,000 cycles per second. The power supply, such as the inverter, or an oscillator and amplifier may be contained in, or partially or completely remote from, the blade support means. Piezoelectric as well as magnetostrictive transducers are described.

This application is a continuation-in-part of my earlier filed application Ser. No. 431,606, filed Feb. 10, 1965, now abandoned.

This invention relates to shaving instruments and more particularly to an electromechanical razor.

Razors having motor-driven cutting edges which describe rotary and oscillatory and vibratory motion have been in common use for a considerable time. These known electromechanical razors have not been unsatisfactory, but their performance has left much to be desired. For most persons, shaving is a very personal and individual experience both physically and psychologically. What is a more or less satisfactory performance to one person may be quite unsatisfactory to another person.

Out of my experience with shaving instruments of many kinds, it became apparent to me that most of the known electromechanical shavers generally fall short of wholly satisfactory performance because they have been designed with a view to duplicating more or less closely the fundamental cutting action of straight edge razors and safety razors. Other shaving instruments have been made in which the cutting edges of electromechanical razors are vibrated at frequencies approximating the upper limits of the audio range. My investigations into the mechanical properties of hair and of the essential nature of the mechanism of cutting hair with a blade revealed to me that none of the designs of existing electromechanical shaving instruments were based on a full understanding of the nature of the problems involved. The resulting cutting instruments are not capable of severing individual hairs while transmitting to the nerve ends in the skin a minimum of the irritating forces which cause stinging and burning sensations during and after shaving.

My investigations have shown that the pressure required to cause a conventional razor blade to sever the hard substance of a human hair is of the same order of magnitude as that required to sever aluminum or copper in wire form. I have found that this pressure approaches 30,000 pounds per square inch. With these and other new facts at hand, I have invented an entirely new shaving

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instrument which is so conceived and designed as to drive the cutting edge of the blade or other cutting means against the individual hairs with extremely high impact forces whereby the mechanism by which the hair is several depends in large part upon inertial forces between the hair and the impacting blade and to a much lesser extent upon the ordinary static forces between the cutting edge and the relatively immobile hair anchored in the skin.

According to my invention my new shaving instrument or razor comprises vibratory cutting means having a cutting edge thereon. I provide vibratory electromechanical transducing means coupled to the cutting means and adapted to vibrate the cutting means at ultrasonic frequency. The shaving instrument or razor according to my invention is also provided with means for exciting the transducing means at ultrasonic frequency. The combination of these elements results in the edge on the cutting means being forced to vibrate at ultrasonic frequency such that, while the amplitude of vibration may be very small, the acceleration and hence, the impact forces between the cutting edge and a hair are extremely high and create highly localized forces in the form of high-frequency vibrations, shock waves, local heating and sawing and chiseling actions which are coupled to the individual hairs as the razor is advanced along the face as in normal shaving. These extremely high accelerations overcome the elasticity and shear strength of the hair fibers, thereby severing them without pull, drag, or other sensation and at the same time producing a smooth, clean shave.

In the following specification I give a detailed description of a particular embodiment of my invention. In the course of the description reference is made to the accompanying drawings in which

FIG. 1 is a perspective view of a razor according to my invention;

FIG. 2 is a front elevation of the razor illustrated in FIG. 1;

FIG. 3 is a sectional view taken along the line 3—3 of FIG. 2;

FIG. 4 is an enlarged perspective of the blade driving mechanism for the razor shown in FIGS. 1–3;

FIG. 5 is an enlarged view in section of a modification of the razor shown in FIGS. 1–4; and

FIG. 6 is a perspective view of the blade and blade driving mechanism of the razor shown in FIG. 5;

FIG. 7 is a vertical sectional view taken through a portion of another embodiment of the razor unit of the invention showing the blade and blade support means thereof, wherein flexural mode of transducer vibration is used.

FIG. 8 is a side view of a crystal unit of the invention, illustrating one mode of vibration thereof;

FIG. 9 is a side view of another type of crystal unit useful in the invention, showing the mode of vibration thereof.

FIG. 10 is a schematic drawing showing the operation of an electronic inverter power supply means which is useful with the present invention.

In FIGS. 1 and 2 I have illustrated the external configuration of a razor embodying my invention. This comprises essentially a shaving head indicated at **1** and a handle indicated generally at **2**. It should be understood that the external appearance and the relative arrangements of the shaving head and the handle are not a part of the invention. The form illustrated in FIGS. 1 and 2 is simply one convenient form in which the components of the invention may be associated. In this particular form, the shaving head ressembles in many respects the external appearance of a commercially available single-edge safety razor.

The shaving head 1 comprises a frame consisting of upper and lower plates 3 and 4 which are joined together at the back by the wall 5, the three components just mentioned being a unitary member in this embodiment. As best seen in FIG. 1, the plates are spaced apart toward the rear to form a housing for components to be described. As is also shown in FIG. 1, the plates converge toward the forward part of the frame such that the forward edge 6 of the upper plate 3 converges on the lower plate 4 and is preferably designed so that this forward edge would bear on the lower plate but for the interposed blade indicated at 7.

On the forward edge of the lower plate 4 there is a conventional guard bar 8 which assists in positioning the cutting edge of the blade 7 in relation to the skin during shaving. At the opposite ends of the guard bar there are blade stops 9.

The shaving head 1 is joined to the handle 2 by a neck 10 which may be forced as an integral part of the shaving head 1. The handle may be formed of any suitable material such as a cast or molded synthetic resin and may be provided with knurling as indicated at 11 to give an attractive appearance and to provide non-slip gripping surfaces.

In the embodiment illustrated in FIGS. 1 and 4, the blade 7 is provided with a cutting edge 12 and an oppositely disposed rear edge or driving edge 13. The blade is clamped in position between the forward edge 6 of the upper plate 3 and a fulcrum ridge 14 raised above the surface of the lower plate 4. To insure that the blade remains in this clamped position, the fulcrum ridge 14 rides in a longitudinal fulcrum groove 15 provided in the blade at a location between the cutting edge 12 and the driving edge 13 which is preferably at or near a vibrational node. The significance of this will be described in greater detail below.

Within the space between the upper plate 3 and the lower plate 4 to the rear of the driving edge 13 of the blade, there is located an electromechanical transducer which in various embodiments may be a quartz, barium titanate, or other like crystal 16, or a ceramic material described further herein. The crystal is cut so that its natural frequency is on the order of 100 kilocycles. The crystal is enclosed in a suitable casing 17 which is resiliently held in position within the shaving head of any suitable means such as one or more leaf springs 20. The forward portion of the casing adjacent the driving edge 13 of the blade 7 is provided with a channel member 21 into which is fitted the driving edge of the blade; thus, the blade is vibrationally coupled to the crystal.

The crystal frequency of 100 kc. is stated for illustrative purposes only. According to my invention the blade may be driven by a crystal or other suitable transducer having a vibrational frequency or frequencies within a range extending from approximately 100 kc. upwards to approximately 4 megacycles. I have found that the hair severing action described above as characteristic of this invention predominates within this range and may even persist to a lesser extent at frequencies beyond this range.

As is shown in FIG. 3, I provide in the handle 2 a void 22 in which is located a high-frequency generator 23 of any suitable design capable of producing alternating voltages at the resonant frequency of the crystal 16. The generator is designed to be energized by a commonly available source of power such as by batteries or by a 110 volt, 60 cycle electrical source which is connected to the input of the generator through a line cord 24. The output of the generator is connected to the crystal through the leads 25 which pass from the void 22 upward through a passage 26 in the handle 2 and into the space between the upper plate 3 and the lower plate 4 where the leads are connected to appropriate connections 27 on the crystal 16.

Referring now to FIG. 10, there is shown a schematic diagram of an electrical circuit comprising a power source or high frequency generator 23, which in this case, is in the form of a battery powered inverter. This unit 23 comprises a small size, high frequency transformer core 32 having a primary winding 33, a feedback winding 34, and an output or secondary winding 35. Two leads 25 extend to either side of a piezoelectric element 16, which in this case is a lead zirconate-lead titanate ceramic material, having a width of about one quarter of an inch, a length of about one half an inch, and a thickness of about one quarter of an inch.

I used a piezoelectric ceramic which had a principal mode of vibration in the longitudinal extensional mode, namely a so-called PZT–4 crystal, obtained from the Clevite Corporation, of Bedford, Ohio. Other devices may be used, such as other ceramics, lead titanate crystals, barium titanate crystals, ammonium dihydrogen phosphate crystals, Rochelle salt, ethylene diamine tartrate, dipotassium tartrate, tourmaline, and lithium sulfate.

An output alternating voltage of 100,000 cycles per second, for example, is impressed across the element 16, as will now be described, for causing vibrational longitudinal extension of the element 16.

The primary winding 33 of the generator or inverter 23 is center tapped at 36, and connected to a 2.5 volt positive terminal of a battery or other D.C. source 37. A filter capacitor 38 is connected in parallel with the D.C. source 37. The negative voltage lead 39 is split and connected to the collectors 40, 41, respectively of transistors 42, 43. The bases of the transistors 42, 43 are connected to each other through the feedback winding 32, which is inductively coupled to the core 32, while the emitters of the transistors 42, 43 are connected to each other through the primary winding 33. Thus, in operation, an oscillating current is impressed on the core 32, and is coupled to the output winding 35. The lead 39 from the negative side of the D.C. source 37, in addition to being connected to the transistor collectors, is also connected at 44 to the center tapped feedback winding 34, with a parallel R-C network comprising a resistor 45 and a capacitor 46 connected at 47, 48 into the line 39. The values of the capacitors 38, 46 are selected to provide proper filter action and a desired resonant frequency; for example capacitor 38 may have a 2 microfarad rating and capacitor 46, a 0.5 microfarad capacity. Using 2N 2912 transistors, for example, a satisfactory inverter is obtained, which operates at 100,000 cycles and above.

If a battery 37 is provided as shown, the cord 24 shown in FIG. 3, for example, may be eliminated. If desired, however, rectified alternating current (A.C.) may be supplied through the cord 24, or A.C. may be supplied and rectified in a conventional, known manner before being fed to the inverter.

FIG. 8 shows a lead zirconate-lead titanate ceramic piezoelectric transducer 16, and illustrates the mode of vibration thereof. The normal position is shown in heavy lines, with the longitudinally extended, diminished thickness form shown in phantom lines. As the alternating voltage or polarity is impressed on this transducer, it changes between these forms at the frequency of the impressed voltage.

In another embodiment, it may be desired to have some portions of the power source or the entire power source, located remote from the handle portion 2 as well as remote from the shaving head 1.

In such a case, I have successfully operated the unit with an oscillator generally known as a General Radio Company oscillator Model 1210–C, the output signal of which may be fed to a tube type amplifier, such as a General Radio model 1233–A amplifier, before being fed to the crystal or other transducer 16.

Such a type 1210 oscillator has a frequency range of 20 to 500,000 cycles per second, and is a series-parallel, resistance-capacitive network type oscillator, the exact design of which is shown and completely described in a booklet entitled "Operating Instructions, Type 1210–C Unit, R–C Oscillator," (Form 1210–0100–H), dated August 1964, published by the General Radio Company, West Concord, Mass. Likewise, a booklet entitled "Operating Instructions," Form 1233–0100–E, dated April 1965, and published by General Radio Company, describes in great detail the type 1233–A power amplifier, which is basically a three stage push-pull electron tube type amplifier.

In the electromechanical transducer art, it is well known that, in addition to fundamental resonant vibrational frequencies, the crystals or other transducers have various harmonics which are low numerical integral or fractional multiples of the fundamental frequencies. Although I prefer that the vibrations of the crystal occur at the fundamental frequencies thereof, it is not necessary that they so occur.

FIGS. 5 and 6 illustrate an alternative embodiment of the invention in which a blade **7** is mounted in the head of the razor and clamped between a fulcrum ridge **14** on the lower plate **4** and the forward edge of the upper plate **6** as in the embodiment shown in FIGS. 1 to 4. Similarly, a blade driving piezoelectric crystal **16** is mounted in the rearward portion of the cavity in the shaving head and is resiliently supported in this position by a leaf spring **20**. In this modification the efficiency of the vibrational coupling between the crystal **16** and the driven edge **13** of the blade is greatly enchanced by the provision of a mechanical transformer **28**. The transformer may be made of any suitable material such as metal or plastic which is sufficiently rigid at the driving frequency of the crystal to transfer substantial energy to the blade **7**.

Referring now to the operation of these razor units, it should be understood that, in the embodiment shown in FIGS. 3, 5, and 6, the function of the transformer means **28** is to gather energy from the crystal and impart the energy to the blade. Thus, the rear face of the transformer **30** is much larger than the forward face **31** thereof, and the shape of the transformer **30** is such that energy is concentrated before being imparted to the blade.

Although the exact reasons for the operation of this unit are not known with certainity, it is believed that the blade itself does not ordinarily, and certainly does not necessarily, vibrate with exactly the same vibrational characteristics as the crystal. Thus, the entire blade is not necessarily moved solely longitudinally forwardly and backwardly along its length at the frequency of, and with the amplitude of, the crystal or ceramic transducer. It is believed that longitudinal waves fed into the back edge of the blade travel toward the front edge, but are at least partially reflected back into the blade when tending to leave the blade. When the waves reach the beveled edge portions of the blade, reflections thereof occur, and cause a change in wave pattern to a shear effect. The geometry of the blade edge is such that these waves are "collected" at the edge of the blade, and the low mass blade edge is activated with considerable energy, although not necessarily energy from synchronous movement of the entire blade back and forth at the fundamental frequency of the transducer. Obviously, the resilience, strength, and other characteristics of the material comprising the blade, as well as the exact geometric shape thereof, determine the exact behavior thereof. However, it is not a necessary part of the invention that the blade itself vibrate in any exact mode, only that the energy supplied thereto is vibrational ultrasonic energy of the type referred to herein.

Referring now to the ridge **14**, the groove **15**, and the forward edge **6** of the upper plate **3**, used to hold the blade **7** in position, the line defined by the groove **15** should be at a vibrational mode. However, it is not a necessary part of the invention that the blade itself vibrate in any exact mode, only that the energy supplied thereto is vibrational ultrasonic energy of the type referred to herein.

Referring now to the ridge **14**, the groove **15**, and the forward edge **6** of the upper plate **3**, used to hold the blade **7** in position, the line defined by the groove **15** should be at a vibrational node. However, it is not necessary, for reasons which are not understood with certainty, that the node be predetermined, calculated or empirically located, in all cases, since it has been discovered that holding or supporting the blade in the manner described may actually serve to create a node at that point. In other words, a blade in contact with a member having ultrasonic driving energy can be made to have various apparently natural resonant frequencies, and holding or supporting it in a particular way will be one of the factors which determine such fundamental or natural resonant frequencies, or overtones or undertones thereof.

Referring now to FIGS. 7 and 9, a further alternate construction is shown, in which the transducer comprises a pair of crystal units **49**, **50**, adhesively attached to each other to form a unitary piezoelectric transducer having a flexural mode of vibration. A mechanical transformer **51** attached to the upper end of the transducer supports a blade **52**, which is disposed with a cutting edge portion **53** thereof spaced apart from the guard **54**. Leads **55** supply an alternating voltage from the power source, such as that shown at **23** in FIGS. 3 and 10, to the lower end of the transducer, which is held by spring-like clamping means **56** in a fixed position within the head **57**. A fulcrum **58** supports the blade **52** along a groove **59** therein. In other details, the razor is similar to those shown in FIGS. 3 and 5, for example. The type of power supply is also optional in this case; an inverter powered by a D.C. source, or an oscillator-amplifier combination may be used, for example.

In the operation of this unit, the alternating voltage causes a face shearing or transversely expanding action in each crystal, and the result is a deflection or flexural action at the free end of the composite transducer. This composite transducer creates a higher amplitude, lower force type motion than a single element transducer. In this construction, a single element crystal having a flexural vibrational mode may be substituted for the composite unit. The vibrational energy of the transducer, in operation, is supplied to the blade, and the vibratory action of the blade is substantially the same as that described in relation to the other embodiments of the invention.

The phantom lines in FIG. 9 show the vibrational mode of the transducer under the influence of an applied alternating voltage. The materials which comprise the piezoelectric transducers may be cut from naturally occurring crystals, or may be pressed from powders or the like. In the case of ceramic materials, these are originally polycrystalline in nature, until piezoelectric properties are induced therein by a polarizing treatment ("poling"). The transducers used for producing longitudinal extension were typically so-called 0° X-cut materials (major face cut perpendicular to the X-crystallographic axis, edges parallel to Y and Z axes). For the elements of the transducer vibratory in the face shear mode, a so-called DT cut or SL cut is appropriate such cuts being well known to those skilled in the art of piezoelectric crystals.

The configuration of the mechanical transformer is best seen in the perspective view of FIG. 6. In cross section the transformer tapers from a relatively thick portion at the rearward face **30** where it is coupled to the crystal to a thin section at the forward edge **31** where the transformer couples to the driven edge **13** of the blade.

It would, of course, be possible to drive the blade by other transducer means such as a magnetostrictive device in place of the piezoelectric crystal, provided that the driving means is capable of oscillating within the range of frequencies contemplated by the invention. Typical magnetostrictive device are ferrite materials of many sorts, particularly those of an E-core shape with legs thereof inductively wound with coils having an ultrasonic output frequency.

As previously pointed out, prior inventors have attempted to provide mechanical and electromechanical drives for the cutting edge of a safety razor but these have not been successful because the mechanism of cutting hair was apparently not fully understood and the driving frequencies which were tried by the prior art workers were too low by many tons of thousands of cycles. In accordance with my invention, the frequency at which the blade edge is driven must be within the range of approximately 100,000 cycles per second upwards to approximately 4 million cycles per second with the desirable effect persisting to a lesser extent beyond this range. Once the art is informed of this requisite, it then becomes apparent why I have mounted the blade **7** in the particular manners shown in FIGS. 3 and 5.

The clamping of the blade along a line intermediate its cutting edge and its driven edge is one good means for decoupling the blade from the shaving head. This accomplishes two things. First, the vibrational energy is not transferred to the shaving head and, second, the restraint on the vibration and oscillation of the cutting edge of the blade is minimized. The ideal position at which the blade should be clamped is, of course, at a vibrational node between the cutting edge and the driven edge of the blade. In general a node will occur an integral multiple of a half wave length from the driven edge of the blade. The place at which the blade is clamped will depend on the resonant properties of the blade itself and upon the frequency at which the crystal drives the blade. Taking into consideration these and other relevant factors such as the distance between the cutting edge and the driving edge, it will be apparent to those skilled in the art of vibrational systems that in any given system, there may be one or several nodal lines along which the blade may be clamped. Moreover, in some systems and using particular crystals, a designer may couple the driving crystal to the blade in such a way that the blade is effectively operated at a harmonic frequency of the crystal rather than at its fundamental frequency.

By the term "ultrasonic" as set out in the specification and claims hereof, it is intended to be meant frequencies which are not only well above so-called audio frequencies, that is, frequencies up to about 20,000 cycles per second but also frequencies greatly in excess of such frequencies, the term "ultrasonic" being intended to include frequencies up to 4 or 5 megacycles or more, such frequencies in various other arts being sometimes referred to as radio frequencies, intermediate frequencies and very high or ultra-high frequencies. These and other variations are intended to be within the scope of my invention which is defined in the following claims.

I claim:

1. A razor unit comprising, in combination, razor head means, blade guard means associated with said head means, electromechanical transducer means disposed at least partially within said head means and supported therein so as to allow ultrasonic vibrational movement of at least a part thereof in response to an alternating voltage impressed thereon, cutting means mechanically coupled to a portion of said transducer means, said cutting means including a cutting edge portion thereon, said cutting edge portion extending at least partially outwardly of said razor head means, and power source means electrically connected to said transducer means for impressing an alternating voltage thereon at an ultrasonic frequency, whereby, upon operation of said power source means, said transducer means vibrates at an ultrasonic frequency, and transfers vibrational energy to said cutting means.

2. A razor unit as defined in claim **1** in which said transducer means and said power supply means are operable at a frequency of from about 100,000 cycles per second to about 4,000,000 cycles per second.

3. A razor unit as defined in claim **1** in which said transducer means comprises a piezoelectric ceramic material.

4. A razor unit as defined in claim **1** in which said transducer means comprises a piezoelectric crystal.

5. A razor unit as defined in claim **1** in which said transducer means comprises a magnetostrictive element.

6. A razor unit as defined in claim **1** in which said cutting means comprizes razor blade means, and in which said razor blade means is supported along a line parallel to said cutting edge portion, said line lying intermediate said cutting edge portion and the edge portion of said blade means which is opposite said cutting edge means.

7. A razor unit as defined in claim **1** which further includes handle means thereon, and in which said power supply means comprises an electronic inverter unit disposed within said handle means.

8. A razor unit as defined in claim **1** in which said power supply means comprises electronic oscillator means having a normal output of an ultrasonic frequency, and an electronic amplifier means for amplifying the output of said oscillator means.

9. A razor unit as defined in claim **1** in which said transducer means comprises a composite piezoelectric unit having two elements thereof fastened together, said elements having similar modes of vibration, and wherein said piezoelectric unit is held at one end thereof, is free to vibrate flexurally at another end thereof, and wherein said cutting means is mechanically coupled to said composite piezoelectric unit.

10. A razor unit as defined in claim **1** which further includes mechanical transformer means for coupling said cutting means to said transducer means.

11. A razor unit as defined in claim **3** in which said ceramic material is a lead zirconate-lead titanate material having a longitudinal vibrational mode for imparting energy to said cutting means at an ultrasonic frequency.

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