

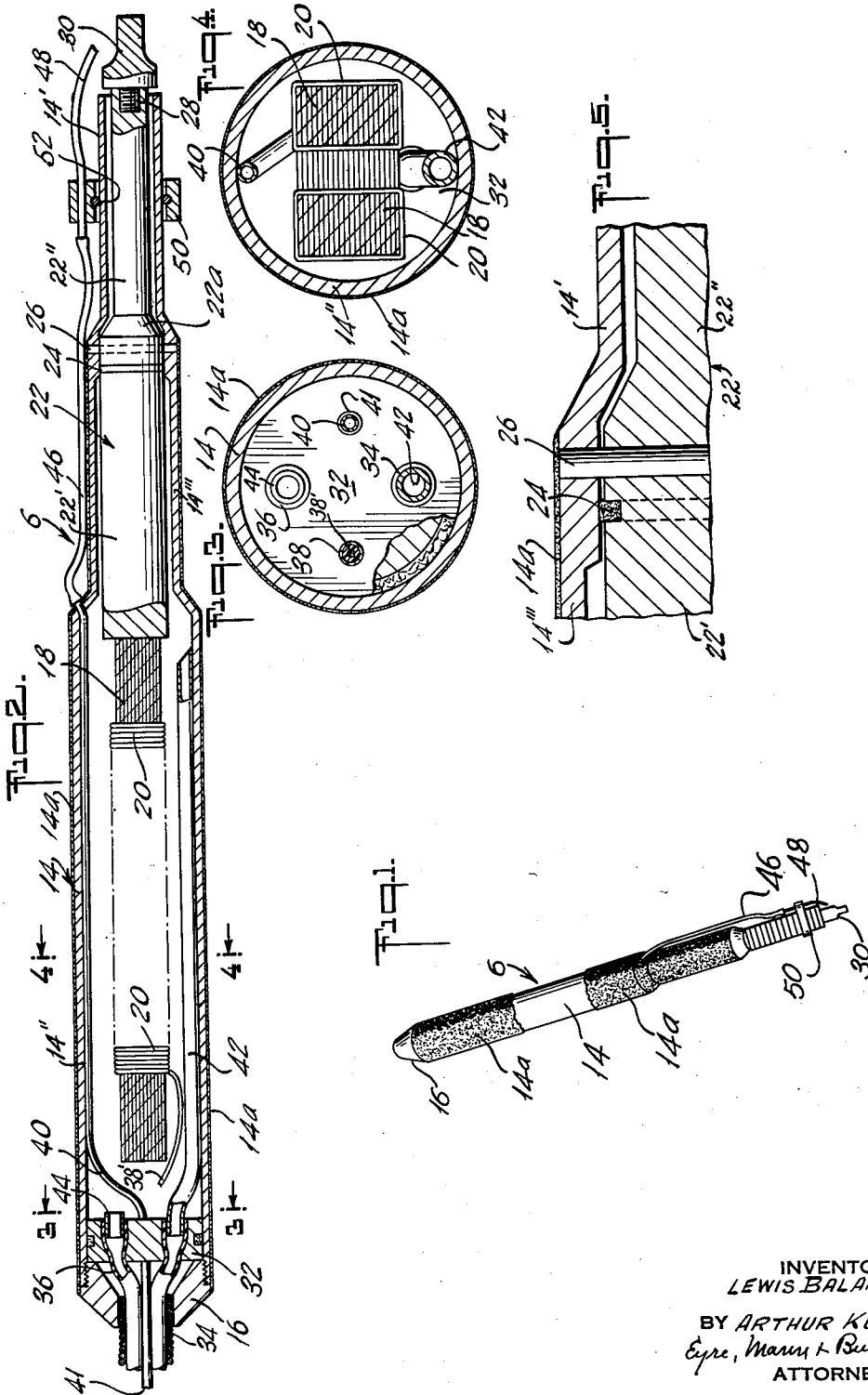
Jan. 29, 1963

L. BALAMUTH ET AL  
DENTAL INSTRUMENT

3,075,288

Filed Dec. 24, 1954

2 Sheets-Sheet 1



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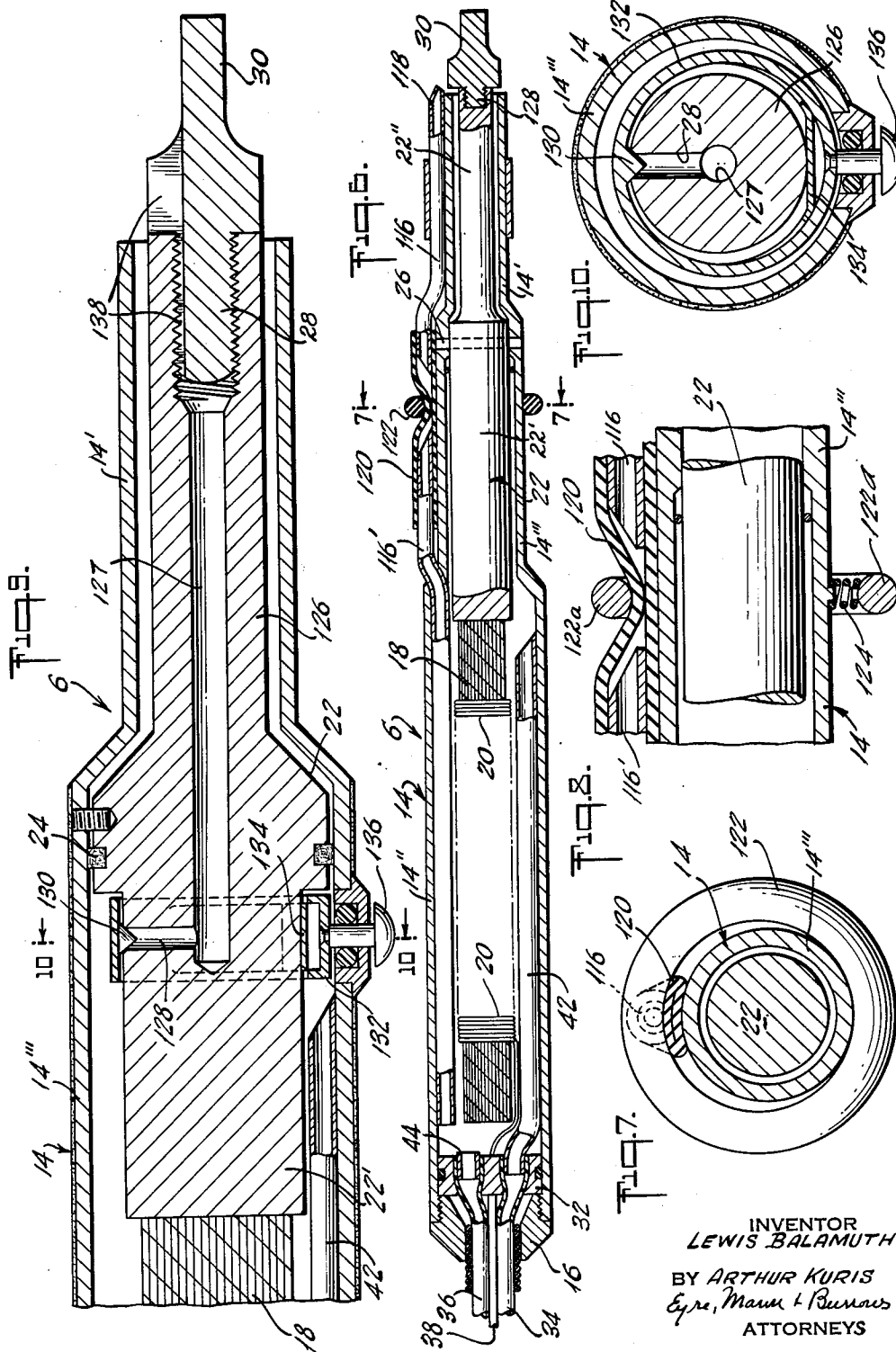
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1

3,075,288

## DENTAL INSTRUMENT

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11 Claims. (Cl. 32—58)

The present invention relates to sonic and ultrasonic instruments particularly designed for use by the dental and surgical profession.

Sonic and ultrasonic cutting, as described in Balamuth U.S. Patent No. 2,580,716, issued January 1, 1952, is practiced by the use of a tool in which high frequency longitudinal vibrations of minute amplitude are set up by an electro-mechanical transducer, for example, a magnetostrictive transducer. Abrasive, in finely divided form and suspended in a liquid, usually water, is interposed between the work to be cut and the vibrating end of the tool. When pressure is applied to advance the tool into the work, the abrasive particles which are highly accelerated as a result of the vibrations at the working end of the tool, cut the work and produce holes or cavities therein having cross-sectional configurations conforming to that of the tool.

Prior to the present invention the above briefly described process has been employed in industry for cutting or drilling hard and/or brittle materials such as carbides, crystalline gem stones, germanium, ceramics and hardened tool steels. The specific ultrasonic devices heretofore in use were not specifically designed for cutting or drilling teeth. As a result of study of dentists' requirements for ready use of their professional skill, we have developed a dental instrument which operates on the principles disclosed in said Balamuth patent and which differs radically from the conventional dental drill. The new instrument is substantially painless and entirely harmless to the patient; it utilizes the previously acquired skill of the dentists; it reduces chair time on conventional operations and it can perform operations and obtain results unobtainable by conventional dental drills.

Production of a commercially practicable ultrasonic dental instrument involved the solution of many problems such as, the mounting of the vibrator within a hand piece whose dimensions correspond to those of a conventional dental drill; the provision of a small size vibrator comprising an efficient magnetostrictive transducer and tool holder; and the provision of means for supplying electrical energy to the transducer, means for cooling the transducer, and means for supplying cutting liquid and treating fluid to the work area of the tool; all without restricting the manipulation of the hand piece by the operator.

In the foregoing we have briefly outlined some of the problems encountered and solved in the production of the new dental instrument of this invention. The new instrument comprises in general a hand piece substantially of the size of the conventional drill to one end of which a small dental tool of any desired configuration may be attached. The hand piece comprises an open ended casing housing a vibrator which includes a magnetostrictive transducer and a tool holder or acoustical impedance transformer fixed to one end of the transducer, and which provides an acoustical transmission line between the transducer and work tool. The vibrator is mounted in the casing by means of a ring of compressible material located in the neighborhood of a node of longitudinal vibration of the tool holder, when compressional waves of the operating frequency are generated by the transducer, means being provided for

2

preventing relative rotation between the casing and the tool holder. For maximum amplitude of vibration of the tool end, and for maximum transmission of working energy, the overall length of transducer, transformer and tool, is so correlated to the frequency of the electrical oscillations delivered to the transducer, that a loop of motion of the generated compressional waves will occur at or near the working end of the tool. In other words, the overall length of transducer, tool holder and tool are approximately equal to an integral number of one-half wavelengths of sound waves in the particular materials comprising the transducer, transformer and tool at the working frequency.

The end of the casing encompassing the transducer is made to accommodate a water inlet tube which enters into the casing through a removable plug or closure for that end of the casing and extends for substantially the length of the transducer. A short tube extending through the plug provides the outlet for the cooling water. The compressible mounting ring serves to prevent uncontrolled leakage of cooling water to the tool end of the casing, and permits radial expansion and contraction of the transformer. The transducer comprises a laminated stack of magnetostrictive metal sheets about which is wound a conductor provided with a water impervious insulating coating. The winding may be threaded through aligned slots formed in the thin magnetostrictive sheets or plates which form the laminated stack. A concentric cable comprising an inner insulated conductor and an outer grounded metallic cover enters the casing through the closure plug. One end of the transducer winding is connected to the inner conductor of the cable and the other end to the grounded casing.

A capillary tube, terminating adjacent the tool end of the hand piece, is provided for delivering warmed cutting liquid or slurry composed of a mixture of water and abrasive to the work area. Another capillary tube may be provided for delivering water or other treating liquid to the work area under the control of the operator, and which may be used for rinsing the patient's mouth.

The invention also includes alternative arrangements for the delivery and control of the cutting liquid to the work area, as will be apparent as the description proceeds.

For a description of specific embodiments of the invention, reference may be had to the accompanying drawings of which:

FIG. 1 is a pictorial illustration of one form of vibratory instrument made in accordance with this invention;

FIG. 2 is a longitudinal sectional view through the instrument shown in FIG. 1;

FIGS. 3 and 4 are transverse sectional views on a larger scale taken on the lines 3—3 and 4—4, respectively of FIG. 2;

FIG. 5 is a fragmentary longitudinal sectional view showing the means for mounting the tool holder and transducer in the casing of the hand piece;

FIG. 6 is a longitudinal sectional view through a dental hand piece provided with an alternative arrangement for supplying a treating liquid;

FIG. 7 is an enlarged transverse sectional view taken on the line 7—7 of FIG. 6, and which further illustrates one means which may be employed to control the flow of treating liquid to the work tool;

FIG. 8 is a fragmentary longitudinal section of the hand piece which incorporates a modified means for controlling the flow of liquid to the work tool shown in FIG. 6;

FIG. 9 is a fragmentary longitudinal section of a hand piece which includes a modified form of tool holder or

3

transformer and modified operator controlled means for supplying liquid to the work tool; and

FIG. 10 is a transverse sectional view taken along line 10-10 of FIG. 9.

The hand supported instrument illustrated in FIGS. 1, 2, 3, 4 and 5 comprises an outer casing 14 of cylindrical cross section. One end section 14' of the casing 14 is of relatively small diameter and is open ended. The other end section 14'' of the casing may be larger in diameter and is internally threaded at its end. A centrally apertured cap 16 is threaded to the larger end of the casing. The two end sections 14' and 14'' are connected by an intermediate section 14''' of intermediate diameter whose length is approximately equal to that of the end section 14' of least diameter. Preferably the outer surface of the casing 14 is covered with a layer 14a of vibration absorbing material, such as rubber having closed air cells therein. Within the section 14'' of larger diameter is a magnetostrictive transducer comprising a laminated stack 18 composed of a series of relatively thin and compactly stacked plates formed of nickel or other magnetostrictive material, and an energizing winding 20 in surrounding relation to the laminated stack as shown in FIGS. 2 and 4. One end of the stack is welded or soldered to an end of a tool holder 22 shaped to serve as an acoustical impedance transformer. The tool holder 22 extends through the intermediate section 14''' and end section 14' of the casing 14 and comprises two body sections 22' and 22'' of different cross section interconnected by a short tapered section 22a. The overall length of the tool holder or transformer 22 is substantially equal to one-half wavelength of standing waves set up therein at the operating frequency, with the tapered section 22a which joins the body sections 22' and 22'' being positioned substantially at the node of longitudinal motion of such standing waves. Magnification of amplitude of vibration is attained by virtue of a mass effect as described in the copending application of Lewis Balamuth and Arthur Kuris, Serial No. 417,707, entitled "Vibratory Machine Tool," filed March 19, 1954, Reissue Patent Re. 25,033. It is at this nodal region that the transformer or tool holder 22, with the transducer stack 18 secured thereto, is mounted within the casing 14 of the hand piece. The mounting means comprises a ring 24 of compressible material, such as rubber, which seats in an annular recess in the transformer or tool holder 22 and forms a yielding water tight seal between the casing 14 and the transformer 22 contained therein. The compressible ring 24 does not appreciably dampen radial vibrations present at the nodal region of the transformer 22 and therefore does not subject the transformer to external stresses.

To avoid interference with the high frequency longitudinal vibrations set up in the tool holder or transformer 22 and tool 30 when the transducer stack 18 is energized, the dimensions of the casing 14 and tool holder 22 are such as to provide clearance therebetween. To prevent relative rotation between the tool holder 22 and casing 14, a transverse pin 26 may be inserted in aligned transverse holes in the casing 14 and tool holder 22 adjacent the nodal region 22a where the longitudinal movement is negligible. The holder 22 is provided at its end with a threaded aperture for reception of a stud 28 carrying a work tool or dental tool 30.

A plug 32, which is held by friction within the larger end of the casing 14 and abuts the cap 16, is provided with four holes therethrough as shown in FIGS. 2 and 3. These four holes receive water inlet and outlet conduits 34 and 36, respectively, a coaxial electrical cable 38 and a capillary tubing 40. The coaxial cable 38 comprises an outer metallic grounded cover which is conductively connected to the casing 14 through the plug 32, and an inner conductor 38' provided with an insulating water impervious coating. The insulated inner conductor 38'

4

forms the winding 20 and is grounded at its end to the stack or to the casing. The coil 20 may be threaded through aligned slots formed in the magnetostrictive plates which compose the transducer stack 18, as in conventional practice and as shown in FIG. 4. The diameter of the casing 14 is such that there is only small play between the transducer and the inner wall of the casing 14. Thus the transducer and tool holder 22 are centered and supported by the resilient O-ring 24, without additional supporting means which could hamper vibration. Extending along the inner wall of the casing 14 adjacent the transducer is a water delivery line 42 which at one end is connected within the plug 32 to the water inlet tube 34 and terminates at its other end adjacent the juncture of the transducer stack 18 with the transformer 22. A short water outlet conduit 44 is carried in the plug 32 and makes connection with the outlet hose 36 therein.

The capillary tubing 40, which connects within the plug 32 to a flexible capillary tube 41, extends through the section of casing 14 containing the transducer and passes out through an opening in the casing 14 located substantially at the junction between the intermediate and large diameter sections 14''' and 14'' thereof. Externally of the casing, tubing 40 is connected by plastic tubing 46 of nylon or the like to a short soft steel capillary terminal tube 48. The tube 48 is brazed to a steel ring 50 slidably supported by an O-ring 52 on the small diameter body section 14' of the casing 14. The soft steel tubing 48 and the ring 50 permit the operator, while holding the hand piece in his hand, to adjust the angular and longitudinal disposition of the nozzle or tip of the terminal tube 48 with reference to the tool end. It is through the terminal tube 48, flexible capillary tubing 46, tubing 40 and flexible tubing 41 connected thereto within the plug 32, that cutting liquid is delivered to the work area at the working end of the tool 30.

The operator manually manipulates the hand piece 6 and the tool 30 associated therewith in substantially the same manner as he would manipulate the hand piece of a rotary dental instrument.

In FIGS. 6 to 10, arrangements for delivering preheated water to the work area are disclosed. In each of these arrangements, the water delivered to the work area is drawn from the cooling water provided for the transducer. In the embodiment of FIGS. 6 and 7 a first small metallic tube 116 is mounted on the outside of the casing 14 over the casing section 14' of lesser diameter and terminates in a nozzle 118 adjacent the tool 30. A second small metallic tube 116' terminates adjacent the plug 32 within the chamber formed by the section of the casing 14 of larger diameter. A compressible tube 120 connects the two metallic tubes 116 and 116' whose adjacent ends are cut off in planes of approximately 45° to the axis of the tubing. An expansible ring 122 of rubber or the like encircles the intermediate section 14''' of the casing 14 and is positioned intermediate the interrupted ends of the tubes 116 and 116' and normally collapses the wall of the compressible connecting tubing 120 as shown in FIG. 7. When the operator moves the ring 122 longitudinally along the casing 14 in either direction, the ring 122 rides up the sloping end of either one of the tubes 116 or 116', thereby permitting the collapsed compressible tube 120 to expand and deliver water to the nozzle 118. The water delivered through the tubes 116 and 116' to the tool 30 is warmed by the vibration heated transducer in the chamber of casing 14.

In FIG. 8 an alternative arrangement for controlling the passage of water through the collapsible tube 120 is shown. In this arrangement a ring 122a of non-expansible material encompasses the casing 14 and compressible tube 120. A compression spring 124 is interposed between the inner surface of the ring 122a and the casing 14 at a position diametrically opposite to the collapsible tube 120. Thus when the operator presses on the ring

122a to compress the spring 124, the water passage through the collapsible tube 120 will be opened.

In FIGS. 9 and 10 an internal feed of water to the work area is illustrated. In this construction the tool holder 126 is provided with a longitudinal passage 127 which at its inner end intersects a radial passage 128 which is normally closed by a valve plug 130 carried on the inner surface of a collar 132. A leaf spring 134 mounted within the collar 132 and bearing against the casing 14 operates to draw the diametrically opposite valve plug 130 presented by the inner surface of the collar 132 into valve closing position. The operator, by pressure on a button 136 mounted on a pin extending through the casing wall 14 and connected to the collar 132, may move the collar 132 against the bias of the spring 134 to lift the valve plug 130 away from the passage 128 and thereby permit flow of water through the passages 128 and 127. To permit leakage of water from the passage 127 to the work area, the threaded stud and tool body of the tool 30 used in this embodiment of the invention is provided with a longitudinal slot 138.

It will be apparent from the foregoing description that we have provided an efficient dental instrument which differs fundamentally from dental drills heretofore in use. The new instrument does not require the operator to learn radically new techniques, is simple to operate and, by choice of suitable materials, can be made light to handle. The hand piece parts are relatively simple to construct and assemble. For example, in the embodiment of the invention illustrated in FIG. 2, after the transducer 18 and transformer 22 have been constructed and secured together and the compressible ring 24 mounted in the groove provided therefor, the assembly may be introduced as a unit through the larger end of the casing 14 together with the plug 32 and the parts coupled thereto. The cap 16 may then be screwed into place against the plug 32. Changing from one dental tool to another can be readily effected after the tool holder 22 is thus positioned within the casing 14 and the transverse pin 26 positioned in the mating holes. Obviously a wide variety of shapes of tools can be provided to meet desired cutting operations. As the present invention is not concerned with the specific shape of any one of the tools which might be employed, no attempt has been made herein to illustrate other than the straight tool shown in FIGS. 2 and 9.

It will be apparent that many changes could be made in the specific constructions illustrated in the drawings without departing from the spirit of the invention or the scope of the accompanying claims, and various circuit arrangements for producing the high frequency oscillatory current and the D.C. bias current could be employed.

It will be apparent from the foregoing description, that the specific dimensions of the hand piece will depend to a large extent upon the selected operating frequency, the lower the frequency, the greater the overall length of the hand piece. Although an operating frequency in the upper audible range is entirely feasible, we prefer to employ higher operating frequencies not only to keep small the physical dimensions of the hand piece but also to insure quiet operation. The presently preferred operating frequency is in the order of twenty-nine kilocycles per second.

The following is claimed:

1. A dental instrument comprising a magnetostrictive transducer which includes a vibrator section formed of magnetostrictive material and an energizing coil in surrounding relation thereto, means for connecting said energizing coil to a source of high frequency electrical oscillations, an acoustic transmission section fixed to one end of said vibrator section, said vibrator section and transmission section extending into an open ended casing of a size adapted to be held in and manipulated by the hand of an operator, a dental tool mounted on the other end of said transmission section and protruding beyond the

adjacent open end of the casing, a closure for the other end of the casing, inlet and outlet means extending through said closure for circulating a coolant adjacent said vibrator section, support means for the transmission section and vibrator section interposed between the inner wall of said casing and the transmission section and positioned substantially at the node of motion of longitudinal waves present in said transmission section when said coil is connected to said source, said support means forming a seal between the transmission section and casing, and tubing connected to the coolant inlet and outlet means in said end closure.

2. An instrument comprising an elongated mechanical vibrator having an operative tool fixed to and extending from one end thereof, said vibrator having at least a sectional length thereof formed of magnetostrictive material extending within an energizing coil to form therewith a magnetostrictive transducer adapted to engender at the tool end mechanical oscillations of high frequency and minute amplitude, an enclosing casing containing said energizing coil and vibrator and presenting the operative tool projecting beyond one end of the casing, a closure for the other end of the casing, means which includes a sealing element formed of resilient material for supporting the vibrator in spaced relation to the interior wall of the casing and in spaced relation to said end closure to thereby define a casing chamber between said end closure and said supporting means for the containment of a coolant, and inlet means for admission of coolant into said casing chamber.

3. An instrument comprising an elongated mechanical vibrator having an operative tool fixed to and extending from one end thereof, said vibrator having at least a sectional length thereof formed of magnetostrictive material extending within an energizing coil to form therewith a magnetostrictive transducer adapted to engender at the tool end mechanical oscillations of high frequency and minute amplitude, an enclosing casing containing said energizing coil and vibrator and presenting the operative tool projecting beyond one end of the casing, a closure for the other end of the casing, means which includes a sealing element formed of resilient material for supporting the vibrator in spaced relation to the interior wall of the casing and in spaced relation to said end closure to thereby define a casing chamber between said end closure and said supporting means for the containment of a coolant, a current supply line extending through said end closure and connected to said energizing coil, and a coolant supply line extending through said end closure for supplying coolant to said casing chamber.

4. An instrument comprising an elongated mechanical vibrator having an operative tool fixed to and extending from one end thereof, said vibrator having at least a sectional length thereof formed of magnetostrictive material extending within an energizing coil to form therewith a magnetostrictive transducer adapted to engender at the tool end mechanical oscillations of high frequency and minute amplitude, an enclosing casing containing said energizing coil and vibrator and presenting the operative tool projecting beyond one end of the casing, a closure for the other end of the casing, means which includes a sealing element formed of resilient material for supporting the vibrator in spaced relation to the interior wall of the casing and in spaced relation to said end closure to thereby define a sealed casing chamber between said end closure and said supporting means for the containment of a coolant, said sealing element being positioned substantially at the node of motion of longitudinal waves present in said vibrator when said coil is energized with high frequency oscillations.

5. An instrument comprising an elongated mechanical vibrator having an operative tool fixed to and extending from one end thereof, said vibrator having at least a sectional length thereof formed of magnetostrictive material extending within an energizing coil to form therewith a

7

magnetostrictive transducer adapted to engender at the tool end mechanical oscillations of high frequency and minute amplitude, an enclosing casing containing said energizing coil and vibrator and presenting the operative tool projecting beyond one end of the casing, a closure for the other end of the casing, means which includes a sealing element formed of a resilient material for supporting the vibrator in spaced relation to the interior wall of the casing and in spaced relation to said end closure to thereby define a casing chamber between said end closure and said supporting means for the containment of a coolant, a current supply line extending through said end closure and connected to said energizing coil, a coolant supply line extending through said end closure and into said chamber for supplying coolant to said casing chamber, and a coolant discharge line extending from said chamber through said end closure.

6. An instrument comprising an elongated mechanical vibrator having an operative tool fixed to and extending from one end thereof, said vibrator having at least a sectional length thereof formed of magnetostrictive material extending within an energizing coil to form therewith a magnetostrictive transducer adapted to engender at the tool end mechanical oscillations of high frequency and minute amplitude, an enclosing casing containing said energizing coil and vibrator and presenting the operative tool projecting beyond one end of the casing, a closure for the other end of the casing, means which includes a sealing element formed of resilient material for supporting the vibrator in spaced relation to the interior wall of the casing and in spaced relation to said end closure to thereby define a casing chamber between said end closure and said supporting means for the containment of a coolant, a current supply line extending through said end closure and connected to said energizing coil, a coolant supply line extending through said end closure and into said chamber for supplying coolant to said casing chamber, a coolant discharge line extending from said chamber through said end closure, and a feed line extending through said end closure and terminating at a point adjacent to the terminal end of said operating tool for supplying a flowable treating material to the work area, said tube having a section thereof extending through said chamber and in direct heat exchange relationship with the coolant supplied to said chamber.

7. An ultrasonically operative dental instrument including, a magnetostrictive transducer including a vibrator section formed of magnetostrictive material and an energizing coil in surrounding relation thereto, a tool holder section secured to one end of said vibrator section, a dental tool secured to the other end of said holder section, an open ended casing surrounding said vibrator section and holder section, a resilient sealing element interposed between said casing and holder section intermediate the ends of the holder section and in the neighborhood of a node of motion of the longitudinal vibrations generated by said transducer at the operating frequency, a closure for the transducer end of said casing, and leads to said energizing winding and coolant delivery and exhaust tubes extending through said end closure.

8. An instrument comprising an elongated mechanical vibrator having an operative tool fixed to and extending from one end thereof, said vibrator having at least a sectional length thereof formed of magnetostrictive material extending within an energizing coil to form therewith a magnetostrictive transducer adapted to engender at the tool end mechanical oscillations of high frequency and minute amplitude, an enclosing casing containing said energizing coil and vibrator and presenting the operative tool projecting beyond one end of the casing, a closure for the other end of the casing, means which includes a sealing element formed of resilient material for supporting the vibrator in spaced relation to the interior wall of

8

the casing and in spaced relation to said end closure to thereby define a casing chamber between said end closure and said supporting means for the containment of a coolant, a current supply line extending through said end closure and connected to said energizing coil, a coolant supply line extending through said end closure and into said chamber for supplying coolant to said casing chamber, and a withdrawal line tapping said chamber and terminating at a point adjacent to the terminal end of said operating tool for supplying a tempered coolant warmed by heat energy generated by said transducer to the work area.

9. An instrument for dental and surgical use comprising an elongated mechanical vibrator having an operative tool fixed to and extending from one end thereof, said vibrator having at least a sectional length thereof formed of magnetostrictive material extending within an energizing coil to form therewith a magnetostrictive transducer adapted to engender at the tool end mechanical oscillations of high frequency and minute amplitude, an enclosing casing containing said energizing coil and vibrator and presenting the operative tool projecting beyond one end of the casing, a closure for the other end of the casing, means which includes a sealing element formed of resilient material for supporting the vibrator in spaced relation to the interior wall of the casing and in spaced relation to said end closure to thereby define a casing chamber between said end closure and said supporting means for the containment of a fluid treating material, a current supply line extending through said end closure and connected to said energizing coil, a treating fluid supply line extending through said end closure and said casing chamber to a point adjacent the terminal tip of said operating tool for supplying treating fluid to the work area.

10. Ultrasonic dental equipment comprising in combination, a magnetostrictive transducer including a vibrator section formed of magnetostrictive material and an energizing winding surrounding said vibrator section, a tool holder secured at one end of said vibrator section and designed to support a dental tool at the other end thereof, an open ended casing into which said vibrator section and at least a part of said tool holder extends, a compressible sealing element interposed between said casing and holder intermediate the ends of the holder and in the neighborhood of a node of motion of the longitudinal vibrations generated by said transducer at the operating frequency, a closure cap for the transducer end of said casing having openings therethrough for leads to said energizing winding and for liquid delivery and exhaust tubes, and a pin coupling said casing and tool holder for preventing relative rotation therebetween, said pin extending transversely through the casing and holder in the neighborhood of said compressible element but on the tool side thereof.

11. An ultrasonic dental hand piece comprising, a vibrator section of magnetostrictive material having an energizing coil in surrounding relation thereto and forming therewith a magnetostrictive transducer, an acoustic transmission section fixed at one end to one end of said vibrator section, said vibrator section and transmission section extending into an open ended casing of a size adapted to be held and manipulated by the hand of an operator, a dental tool fixed to the other end of the transmission section and projecting beyond the adjacent end of the casing, a closure for the other end of the casing, liquid inlet and outlet means extending through said closure for circulation of cooling liquid around said vibrator section, support means for the transmission section and vibrator section interposed between the inner wall of said casing and the transmission section and positioned substantially at the node of motion of longitudinal waves present in the transmission section when said coil is energized with high frequency electrical oscillations, said

support means forming a liquid seal between the transmission section and casing.

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