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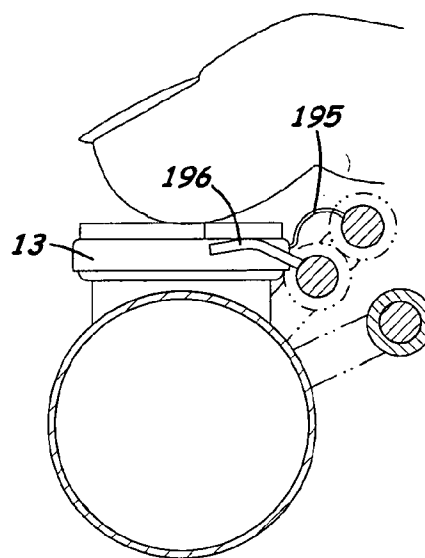
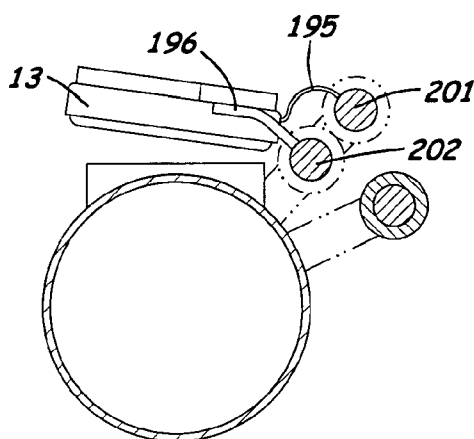
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(54) Title: WIND INSTRUMENT WITH COMPLIANT ACTUATOR STRUCTURES



(57) Abstract: A compliant actuator system is coupled with at least one resonating tube of a wind instrument to effectively shorten and lengthen the air column, making it possible to obtain a range of resonant frequencies. The actuator system opens and closes holes along the tube quickly, easily and quietly within specified tolerances. The compliant actuator system includes multiple compliant actuators that, by the deflection of at least one flexible and preferably-resilient member, transfer energy, motion, or force to a valve or to a combination of valves. The compliant actuator system may also include compliant structure that connects pieces of the actuator system together. Direct and indirect actuator structures are preferably used, for example: 1) direct compliant-actuated valve structure, 2) indirect, simple key compliant-actuated closed or open valve structure and 3) indirect, remote compliant-actuated valve structure. Examples of compliant actuators and structures include a flexible beam, a split tube or other torsional hinge, and C-shaped or other flexural pivots.

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## WIND INSTRUMENT WITH COMPLIANT ACTUATOR STRUCTURES

## DESCRIPTION

This application claims priority of Provisional Serial Number 60/839,230, filed August 21, 2006, the entire disclosure of which is hereby incorporated by this reference.

Background of the Invention

[0001] This invention relates to a wind instrument such as a flute, clarinet, saxophone, piccolo, bassoon, oboe or other instrument provided with a hole closure system. Such a wind instrument comprises a basic body in which extends at least one central tube providing a resonating air column in response to the operator blowing into the instrument. Formed in the tube wall of the central tube are a number of holes that connect the air column with the surrounding air. At least a number of these holes may be opened and closed by means of an actuator system mounted on the instrument. The length of the resonating air column, and, hence, the resonant frequency in the tube, is determined by the open or closed condition of individual and/or groups of said holes during the playing of the instrument. The invention relates more specifically to an actuator system that comprises compliant members that resiliently flex/deflect to provide opening and/or closing means, and/or biasing means to maintain said holes closed or opened, as appropriate for the particular hole of the particular instrument's fingering system.

Related Art

[0002] In conventional wind instruments of this type, the actuator system is the Boehm system, which was developed in the 1800's by Theobald Boehm and is well-known in the art. This system made it possible to open or close finger holes remotely using covers, keys, levers, and shafts. The Boehm system is an intricate mechanical system of hinges, springs, screws, and levers used to transfer or transform energy; the Boehm system is based on rigid links connected at movable

joints. Those familiar with the art will recognize the complexity and intricacy inherent in this system.

[0003] The number of pieces in the Boehm actuator system adds great cost in the manufacturing of wind instruments. For good operation of the wind instrument, it is essential that the many pieces of the Boehm system be maintained periodically by screw adjustments, oiling and replacement of springs, corks, felts and pads. This work is time- consuming and costly because it must be performed by a trained repairman. It must be manufactured out of a material that will maintain its shape overtime and can be soldered for repair.

[0004] Objects of the present invention include providing a wind instrument, of the type that requires hole closure and opening, that is preferably less expensive to make, less expensive and difficult to repair or replace, and/or lighter-weight than conventional complex hole closing and opening systems.

#### SUMMARY OF THE INVENTION

[0005] The invention comprises an actuator system for a wind instrument for controlling the effective length of the resonating air column, wherein the actuator system comprises multiple compliant actuators. Also, the invention may comprise wind instruments comprising embodiments of said actuator system.

[0006] The actuator system provides the structure for opening and/or closing valves and for connecting that structure together. The compliant actuators of the actuator system transfer energy, motion, or force with the deflection of at least one flexible member or a flexible portion of at least one member for said opening and/or closing of the valves. The actuator system may comprise one or more different types of compliant actuators to allow for the variety of mechanism responses desired. For example, a direct compliant actuator may be used when the direction and the location of a valve motion is the same as the operator motion. An indirect compliant actuator may allow for valves to be opened or closed via change of direction and/or change of location of the operator motion through translation and rotation, for example, a simple key that is pressed to open or close a nearby valve. In an indirect compliant actuator, the location of operator motion typically

comprises the operator pressing on a finger-contact member that is some distance from the valve being opened or closed, for example: a) adjacent but not directly over said valve, b) distanced from said valve in a circumferential direction (around the tube from said valve), and/or c) significantly distanced (a “remote” actuator) from said valve typically in the longitudinal/axial direction on the tube. A remote compliant actuator may use levers to aid other actuators and/or to aid the flexure of structures to open or close the valves over distances in which torque may be an issue.

[0007] The preferred embodiments comprise a plurality of direct compliant actuators and a plurality of indirect compliant actuators. In many embodiments, the direct compliant actuators comprise compliant beams that connect caps to a fixed point (typically a rigid bar or rigid beam), wherein said compliant beams allow the operator to press directly on the cap to close an opening that is directly below said caps normally open. In many embodiments, said indirect compliant actuators comprise at least one lever that pivots relative to a fixed point (typically a bar or beam) by pivoting on a flexural pivot member to either open or close a cap that is within a relatively short distance (either axially or circumferentially) from the finger-contact end of the lever. In many embodiments, said indirect compliant actuators comprise at least one remote compliant actuator that comprises, in order to transfer force a substantial distance axially up or down the instrument tube: 1) an elongated lever pivoting on a flexural pivot member, and/or 2) at least one lever plus an elongated rotatable bar or tube, wherein the at least one lever pivots on a flexural pivot member, and/or 3) at least one lever plus a hinge. Said flexural pivots and said hinges typically also provide a biasing function. Said hinges may be selected, for example, from a group consisting of: 1) a single, elongated hinge that extends along the location of multiple valves to operatively connect to a plurality of said multiple valves and that is controlled by caps, keys or levers in generally that same location and/or that is controlled by caps, keys, or levers longitudinally (axially) distant from said hinge; and/or 2) a multiple-section hinge wherein said multiple sections are located near different sets of valves and are connected to each other but work independently in response to (are controlled by) caps, keys, or levers

in the respective hinge section's location and/or in response to (are controlled by) distant caps, keys, or levers (including those at or near another of said hinge sections).

[0008] The preferred embodiments may be formed in one piece, or a minimum of pieces that are connected, in such a way that the compliant actuators deflect in the desired manner and in such a way that much or all of the actuator system may be provided and installed as a single unit. Examples of ways the one or more pieces, and the preferred single unit, may be formed include, but are not limited to, plastic mold extrusion or other types of plastic/polymer molding, laser cutting, machining, etc. A one-piece embodiment, or at least a single unit comprising a minimum of pieces, has the features of simplified manufacturing, assembling, and maintaining, and all of these features result in a reduction in cost. Having fewer pieces to form reduces the amount and variety of machining needed. Having fewer pieces also means less to assemble. Having fewer pieces to maintain decreases the amount of wear between parts and also the uneven wear between dissimilar parts.

[0009] The preferred embodiments may also have the features of removability. By using releasable connectors built into the tube or other structure of the wind instrument, the preferred actuator system (including valve covers and actuators and any other associated structure) may be removed and replaced. Reasons for removal may include, but are not limited to, wear between the parts, fatigue, creep or any factor that may alter an embodiment's performance. A more constant level of performance may be achieved by regular replacement of the actuator system. Typically a conventional wind instrument will not receive regular maintenance due to the expense and difficulty of repair. Easy removability and replacement of embodiments may allow a wind instrument operator to execute regular minor repair of the instrument himself or herself.

## BRIEF DESCRIPTION OF THE DRAWINGS

[0010] Figure 1 is a top view of one embodiment of a flute including one embodiment of the invented actuator system with multiple compliant actuators.

[0011] Figure 2 is a partial top view of the embodiment of Figure 1, featuring valves V1, V3, V4, V14 and V15.

[0012] Figures 3A and 3B are generally cross-sectional views taken along the line 3-3 in Figure 2, wherein Figure 3A portrays cap 14 of valve V14 in closed position and Figure 3B portrays cap 14 being opened. Note that the term “generally” is used here and in many of the following views, because, in order to better portray the actuator/valve structure and action, not all of the structure is cross-sectioned.

[0013] Figures 4A and 4B are generally cross-sectional views taken along the line 4-4 in Figure 2, wherein Figure 4A portrays cap 15 of valve V15 in closed position and Figure 4B portrays cap 15 being opened.

[0014] Figures 5A and 5B are generally cross-sectional views taken along the line 5-5 in Figure 2, wherein Figure 5A portrays cap 1 and key 2 (behind cap 1) in open position and Figure 5B portrays cap 1 being closed by pressing on key 2.

[0015] Figures 6A and 6B are generally cross-sectional views taken along the line 6-6 in Figure 2, wherein Figure 6A portrays cap 3 of valve V3 in open position and Figure 6B portrays how cap 3 could be directly pressed and closed without closing cap 4 (that is behind cap 3). While this is not a normal fingering in playing of this flute, this portrayal illustrates the relationship between cap 3 and cap 4.

[0016] Figure 7A and 7B are generally cross-sectional views taken along the line 7-7 in Figure 2, wherein Figure 7A portrays cap 3 and cap 4 (behind cap 3) in open position and Figure 7B portrays how pressing on cap 4 closes both cap 4 and cap 3.

[0017] Figure 8 is a partial top view of the embodiment of Figure 1, featuring valves V5, V7, V8, V9, and V17.

[0018] Figure 9A and 9B are generally cross-sectional views taken along the line 9-9 in Figure 8, wherein Figure 9A portrays cap 5 of valve V5 and cap 7 of valve V7 (behind cap 5) in open position and Figure 9B portrays cap 5 being pressed to close both cap 5 and cap 7.

[0019] Figure 10A and 10B are generally cross-sectional views taken along the line 10 – 10 in Figure 8, wherein Figure 10A portrays cap 17 of valve V 17 in closed position and Figure 10B portrays cap 17 being opened.

[0020] Figure 11A and 11B are generally cross-sectional views taken along the line 11 – 11 in Figure 8, wherein Figure 11A portrays cap 8 of valve V8 in open position and Figure 11B portrays how cap 8 can be directly pressed and closed without closing cap 9 (that is behind cap 8).

[0021] Figure 12A and 12B are generally cross-sectional views taken along the line 12 – 12 in Figure 8, wherein Figure 12A portrays cap 8 of valve V8 and cap 9 of valve V9 (behind cap 8) in open position and Figure 12B portrays how pressing on cap 9 closes both cap 9 and cap 8. The lever 176, which serves to also close cap 3 (via a torsional hinge,) is shown but cap 3 is not shown.

[0022] Figure 13 is a partial top view of the embodiment of Figure 1, featuring valves V11 and V13.

[0023] Figures 14A and 14B are generally cross-sectional views taken along line 14 – 14 in Figure 13, wherein Figure 14A portrays cap 11 of valve V11 in open position and Figure 14B portrays cap 11 being pressed to close cap 11 and to operate a clutch mechanism that also closes cap 8.

[0024] Figures 15A and 15B are generally cross-sectional views taken along line 15 – 15 in Figure 13, wherein Figure 15A portrays cap 13 of valve V13 in open position and Figure 15B portrays cap 13 being pressed to close cap 13 and to operate a clutch mechanism that also closes cap 8.

[0025] Figure 16 is a partial top view of the end joint of Figure 1, featuring valves V21, V22, and V23.

[0026] Figures 17A and 17B are generally cross-sectional views taken along the line 17 – 17 in Figure 16, wherein Figure 17A portrays cap 23 of valve V 23 in closed position and Figure 17B portrays cap 23 being opened.

[0027] Figures 18A and 18B are generally cross-sectional views taken along line 18 – 18 in Figure 16, wherein Figure 18A portrays cap 21 of valve V21 and cap 22 of valve V22 (behind cap 21) in open position and Figure 18B portrays levers 19 and 20 being pressed to close caps 21 and 22.

[0028] Figure 19 is a perspective view of a combination of one embodiment of a main rigid beam and one embodiment of a multiple-section split tube installed on a flute tube, such as may be used on the flute main section of Figure 1.

[0029] Figure 20 is a detail perspective view of a connection between the main rigid beam, the split tube, and the flute tube of Figure 19.

[0030] Figure 21 is a perspective view of the split tube of Figures 19 and 20.

[0031] Figure 22 is a perspective view of one embodiment of a single-section split tube that may be used in the end joint of Figure 1.

[0032] Figure 23 is a detail view illustrating the interaction of caps upon pressing cap 4.

[0033] Figure 24 is a detail view illustrating the interaction of caps upon pressing cap 9.

[0034] Figure 25 is a detail view illustrating the interaction of caps upon pressing cap 13.

[0035] Figure 26 is detail view illustrating the interaction of caps upon pressing cap 11.

[0036] Figure 27 is a detail view illustrating the interaction of levers and caps upon pressing lever 20.

[0037] Figure 28 is a detail view illustrating the interaction of levers and caps upon pressing lever 19.

[0038] Figure 29 is a schematic exploded view illustrating removal of an embodiment of the main module of the invented actuator system (cap 14 and 15 portion not visible) from the main section of the flute tube, wherein valve numbers and hole numbers are shown.

[0039] Figure 30 is a schematic exploded view illustrating removal of an embodiment of the end joint module of the invented actuator system from the end joint of the flute, wherein valve numbers are shown.

[0040] Figure 31 is a schematic diagram illustrating the preferred interactions of the pieces-parts of the main module (minus the cap 14 and 15 portion) of the actuator system of Figure 1.

[0041] Figures 32A and B, 33A and B, 34A and B, and 35 illustrate examples of alternative compliant actuators that may be utilized in embodiments of the invention.

[0042] Figure 36 is one embodiment of a ring-type cap structure that may be used with embodiments of the invention, wherein a finger surface may form part or all of the sealing structure that cover/blocks the opening of the valve.

#### DESCRIPTION OF PREFERRED EMBODIMENTS

[0043] Referring to the Figures, there is shown the preferred, but not the only, embodiment of the invented actuator system for a wind instrument. There are also shown multiple, but not the only, embodiments of types of compliant actuators that may be used in embodiments of the invention. The preferred embodiment that is portrayed in the Figures is an actuator system adapted for a flute, but parts, portions, or combinations of the parts or portions of the flute actuator system may be applied and/or adapted for use on other wind instruments, for example, on a clarinet, saxophone, piccolo, bassoon, oboe or other instrument using a hole closure system. Once the flute actuator system is understood by a person of skill in the art by reading and viewing this disclosure, said person of skill in the art will be able to adapt the disclosed structure and methods to said other instruments and to add similar or other structure as needed.

[0044] The flute shown in the figures comprises a tube which could be made of many different materials, such as hard plastic, silver, nickel, wood, compound material or composite. When the flute is played, the column of air in the tube is brought into resonance. The resonance frequency, and thus the pitch

produced, depends on the length of the resonating air column. In the wall of the tube are formed a plurality of openings, each of which can be closed or opened by structure that cooperates with the opening. In this description, each opening combined with the structure that removeably covers or blocks the opening is referred to as a “valve.” (See Figures 29 and 30 for valve numbers used herein.) The length of the resonance column is generally determined by the valve opened closest to the blow hole.

[0045] The actuator system comprises structure that serves in one or more of the following categories: 1) finger-contact member that the operator presses, 2) biasing members, 3) actuators that transfer energy, motion, or force caused by the finger to 4) members that cover or block an opening. A single piece or portion of a piece may serve two or more of these functions generally at the same time; in other words, the structures that serve in these operative categories need not be separate pieces or portions. Especially in view of the preferred actuator system being molded or otherwise formed to have portions exhibiting different resilience and flexibility/rigidity, it will be understood that the portions serving these various functions may not always be separate and distinct pieces. For example, different integral portions of a single member may serve multiple of these functions in the preferred embodiments of the invention, as opposed to separate, rigid pieces being connected at movable joints. For example, a single molded or cut piece may comprise a finger-contact portion, a hole blocking portion, and a resilient, flexible member that serves to bias the piece into an open position and serves to allow or transfer motion that moves the piece into the closed position.

[0046] The actuator system illustrated in the Figures, including its individual compliant actuators and its combinations of compliant actuators, may be used to produce the same opening or closing of valves as obtained using the Boehm fingering system. Referring specifically to the figures, flute F comprises three main sections, that are the mouthpiece section M, the main section S, and the end joint E, which slidably connect together by friction fit at joint connections J. In Figure 1, the flute F is cut, for convenience sake, not at connections J but at arbitrary

locations along the length of the flute. The main section S and the end joint E each have their own actuator systems that are typically separate from each other.

[0047] Turning now to the main section S, the actuator system 1001 is preferably a single, removable unit that may be disconnected and lifted from the main section tube 100. See Figure 29, wherein actuator system 1001 (cap 14 and cap 15 portion not visible) has been disconnected from the flute tube as a single unit/module. Main rigid beam 201 and split tube 202 extend substantially the length of the flute tube 100, providing a framework for attachment/connection of the preferred caps, keys, levers, and/or compliant actuators, as further described below. One may see from the following discussion that the preferred main rigid beam is typically a stationary anchor that holds/receives compliant actuators, and the preferred split tube is typically a pivoting/rotating hinge(s) that hold(s)/receive(s) rigid members.

[0048] The main rigid beam 201 preferably does not rotate and does not move significantly or at all, but rather serves as an elongated rigid anchor to which various caps, keys, levers are attached typically by compliant beams, compliant hinges, or compliant pivots. Each of said compliant beams/hinges/pivots preferably comprise both flexible and resilient characteristics, and preferably each serves both as deflectable members and also as biasing members for operating their respective parts of the actuator system.

[0049] Split tube 202 is one but not the only embodiment of a torsional hinge that may be used, and one but not the only embodiment of the preferred hinge type that comprises multiple, independent regions that can be selectively accessed for operable connection of beams or other members from various locations on the wind instrument. Other compliant hinges may be used, for example, by providing a bar with thin, compliant regions on either side of a rigid region.

[0050] The preferred split tube 202 (or other torsional hinge) preferably has multiple sections, each of which is moveable (pivotal/rotatable) to serve as an independently-acting torsional hinge, and to each of which may be attached various caps, keys, or levers typically by rigid beams or rigid connectors. The multiple sections of said split tube 202 (or other torsional hinge) each preferably provide a

pivotal/rotatable attachment location for rigid members, and the multiple sections preferably serve as both deflection members and also as biasing members for operating their respective rigid members or other parts of the actuator system. As discussed earlier in this document, the split tube or other torsional hinge of the preferred embodiments could, alternatively, be supplied as a plurality of separate split tubes or other torsional hinges. Providing multiple sections of a single tube or hinge, rather than separate tubes/hinges, however, contributes to the desired modular or “single unit” feature of the actuator system.

[0051] The actuator system 1001 that provides interaction items A – I below may be formed into a single unit or “single module” made substantially or entirely of plastic, which maybe slid on and off the flute body using releasable connectors C1, C2, C3 built into the flute tube 100 for cooperation with posts C1', C2' and C3'. See Figure 29. The preferred main rigid beam 201 and split tube 202 may be integrally or otherwise connected, directly or indirectly, to posts C1', C2' and C3', so that both beam 201 and tube 202 and all the caps, keys, levers and actuators connected to the beam 201 and the tube 202 may be lifted, slid, or snapped off of the tube 100 with the connected beam 201 and tube 202 as a single “main” module. Therefore, the preferred main module that includes at least 10 caps and the associated actuator structure (in the flute version, the main module comprises 10 caps) is all removable in a single unit by disconnecting the three posts C1', C2' and C3'. Additional caps, keys, levers, and/or actuators may be provided separately from the main module, and may be releasably connected to other portions of the tube; for example, cap 16 and its associated compliant actuator, described below in interaction item M, may be provided as a separate, independent piece (separate module) that can be lifted, slid, or snapped on and off the flute body.

[0052] The actuator system 1002 of the end joint E may be treated similarly as the main section S actuator system 1001. The structure of compliant actuator interaction items J-L below maybe formed into a single unit or “single module” made substantially or entirely of plastic, which may be lifted, slid, or snapped on and off the end joint E using releasable connectors C4, C5 built into the end joint body at the bottom of posts C4', C5'

[0053] When fatigue, creep, or other problems interfere with the performance of the flute actuator system, for example, causing problems in the interactions of the pieces of the actuator system, each actuator system module may be replaced, as needed. If it is determined that one section of the module tends to wear out more often, that section may be separated into its own separate module to allow more frequent replacement of the problem section without replacing the entire module.

[0054] While Figures 1 – 31 illustrate the preferred embodiment, the compliant actuators and hinges shown therein may be modified in many ways without departing from the scope of the invention. “Compliant” herein means transferring energy, motion, or force with the deflection of at least one flexible member or at least one flexible portion of a member, and so there will be other shapes and types of compliant members and ways of connecting them that will be apparent to one of skill in the art after reading and viewing this disclosure. For example, Figures 32A and B illustrate a type of compliant connector 401 used in many places in the preferred embodiment, but Figures 33A and B, 34 A and B, and 35 show additional embodiments 402, 403, 404 of compliant actuators that may be used in the embodiments of the invention. Note that, while member 405 in Figures 34A and B is portrayed as a solid member, it may represent a rigid rod rotatably received in brackets or posts, or may represent a split tube (in which case it should be hollow) or other torsional hinge. Actuator 404 schematically illustrates one, but not the only, type of lever and C-shaped flexural pivot that may be used to remotely actuate the opening and closing of a valve.

#### INTERACTIONS IN THE PREFERRED EMBODIMENT

[0055] The embodiment shown in its entirety in Figure 1 is cut and shown in detail in Figures 2 - 18. Examples of split tube elements are shown in Figures 19 – 22. Figures 23 - 31 illustrate operative connections/interactions of the caps, keys, levers, and actuators of the preferred embodiments and so may be particularly useful in understanding the actuation system of the preferred embodiment.

[0056] Main rigid beam 201 preferably does not rotate or flex; it is fixed or restrained at least at its ends and preferably also near its middle. As shown to best advantage in Figures 19 - 21, that flexible split tube 202 has portions that rotate generally on the tube axis, by means of slits at selected locations along the length of the tube, typically at the two fixed or restrained ends of the tube and at the fixed or restrained middle. Thus, between one slit 203 (near end 208 of the split tube) and the middle slit 205, there is a first unsplit portion 204 that will rotate generally on the axis of the tube 202 by means of deflection/flexing of the tube 202 in the regions of the slits 203, 205. Between another slit 207 (near the opposite end 208' of the split tube) and the middle slit 205 is a second unsplit portion 206 that will rotate by means of deflection/flexing of the tube 202 in the regions of the slits 205, 207. In other words, the slits on each end of an unsplit portion of the tube 202 allow that unsplit portion to rotate generally on its axis to serve as a torsional hinge.

[0057] As discussed earlier in this document, the split tube may be divided into more than two unsplit portions that each act as a torsional hinge, but the preferred embodiment for a flute has been found to work effectively with a two-unsplit-portion split tube. One method of supporting and fixing the ends 208, 208' and the approximately-middle part of the split tube is shown in Figures 19 and 20. T-brackets 209 are fixed to the posts C1', C3' to support and prevent rotation of the ends 208, 208' relative to the posts C1', C3'. Plate C2' ' supports and prevents rotation of a middle part of the tube 202, and optionally may extend to the main rigid beam 201 to become previously-discussed post C2' for fixing/retraining beam 201 approximately near its middle.

[0058] The term "cap" is used to describe a member that is adapted to cover or block a hole beneath it, or that is adapted, with the assistance of a fingertip that covers/blocks part or all of the hole, to cover or block a hole beneath it. The caps drawn in the figures are generally round, solid, plate-like members (typically with a pad or other sealing member on the bottom side), and so it is the cap that performs the function of entirely covering and blocking the hole. It should be understood that other caps, and especially caps used on other wind instruments such as clarinets, may be a ring structure having a hole through the cap, so that closing the cap does

not cover/block the opening unless the operator's finger is present to perform the covering/blocking. See, for example, cap 4'in Figure 26. In normal operation of such caps, the operator's finger presses on the ring-shaped cap and the fingertip is large enough relative to the opening being closed, that the finger actually presses downward and covers/blocks the opening, while the ring cap acts generally as a guide or reference and also as a structure operatively connected to other levers or caps for actuation of other valves. Therefore, in each instrument, some caps are pressed by an operator during playing of the flute (and so may be solid plate-like structures, ring, or other structures), while some are not typically pressed by the operator but are rather operated indirectly (and so should be solid structures that cover/block the opening without the assistance of the finger surface). Therefore, in this description and in the claims, the phrase "caps that are each moveable into a closed position adapted to block a respective opening of said plurality of openings and moveable into an open position adapted to unblock said respective opening" includes caps that are adapted to do the covering/blocking job solely by themselves (for example, by being solid), and caps that are adapted so that part or all of the covering/blocking job is performed by the surface of a finger extending across the opening or across an opening in the cap. Thus, it may be understood that the cap may be the sealing member; the cap may seal around the perimeter of the tube opening but have a hole or holes in it that are sealed by the finger, or the cap may extend around the opening while the finger actually contacts the tube structure forming the opening to be the seal (wherein the ring cap need not have any sealing structure or means).

[0059] The term "key" is used to describe a cap-shaped member that is typically pressed by the operator to indirectly operate another cap, but is itself not a member that covers/blocks a hole beneath it. "Finger-contact member" is a term that includes any of caps, keys, or levers, or other members that the operator will typically press with one or more fingers during playing the instrument; thus, keys, some caps, and some levers are may be called finger-contact members.

Interactions of Main Module Actuator System 1001,  
located on tube 100 of the main section S of the flute:

[0060] A. See especially Figures 1, 2, 5A and 5B. Pressing key 2 closes cap 1 because key 2 and cap 1 are rigidly connected to each other by a rigid beam 150. Rigid beam 150 may extend directly from key 2 to cap 1, across the space between key 2 and cap 1 and parallel to the length of the tube 100, and is fixed to both of said key 2 and cap 1. Each of key 2 and cap 1 are attached to the main rigid beam 201 by a flexible beam 152, 154, in such a way that said flexible beams 152, 154 bias key 2 and cap 1 to an open position distanced slightly from the tube 100 outer surface, and, especially, wherein cap 1 is distanced slightly from its respective hole 101 to open the valve V1. See Figure 29 for hole and valve numbering. Pressing on key 2 serves to close cap 1 and, hence, to close valve V1, but does not move/rotate main rigid beam 201. Key 2 preferably comprises a cap-like “finger-pad” or “finger-contact member” structure the same or slightly larger than cap 1, for accommodating a finger.

[0061] Referring to Figures 5A and 5B, viewed generally along the line 5-5 in Figure 2, there may be seen a cross-section of tube 100, with cap 1 connected by a compliant actuator (flexible beam 152) to the main rigid beam 201. Behind cap 1 (into the paper) is understood to be key 2 connected by compliant actuator (flexible beam 154) to the main rigid beam 201, and rigidly linked to cap 1 by rigid beam 150. When the operator presses on key 2 in Figure 5B, both key 2 and cap 1 move down, and cap 1 covers and seals hole 101.

[0062] B. See especially Figures 1, 2, 6A, 6B, 7A and 7B, 19 and 20 (split tube), and 23. Pressing cap 4 closes valve V4 and also valve V3. Pressing cap 4 closes cap 3 because rigid beam 156 is attached (fixed) to cap 4 and extends to overlap across at least a part of cap 3. When cap 4 is depressed by a finger, beam 156 forces cap 3 down as well. Beam 156 is not attached to cap 3, in order to allow cap 3 to move independently of cap 4 when cap 3 is depressed by other means than cap 4 being depressed. Cap 4 is attached to the main rigid beam 201 by a flexible

beam 160 that biases cap 4 to an open position distanced slightly from the tube 100 outer surface, and, especially, wherein cap 4 is distanced slightly from its respective hole 104 to open the valve V4. Cap 3 is connected to flexible split tube 202 (at unsplit portion 206) by rigid beam 158, but is not attached to main rigid beam 201. As discussed above, the flexible split tube 202 preferably has slits on its ends, near its fixed posts, and also near its middle near a fixed post (roughly half way between its ends) and acts as a torsional hinge for structures such as cap 3 and beam 158 that are connected to it. A torsional hinge uses the angular displacement of elastic members in torsion to obtain rotation, and the length of the slits in the tube determine the strength of the torsional hinge. The unsplit portion(s) of the flexible split tube 202, and rigid beam(s) and cap(s) fixedly connected to said unsplit portion(s) rotate generally on the axis of the tube, as force is applied to the cap(s) (in this example, cap 3), because the splits and the elastic/flexible characteristic of the tube 202 allows said rotation relative to the fixed ends and middle of the tube 202. The flexible split tube 202, therefore, biases cap 3 into an open position distanced slightly from the tube 100 outer surface, and, especially, wherein cap 3 is distanced slightly from its respective hole 103 to open valve V3.

[0063] Referring to Figures 6A and B, viewed generally along the line 6-6 in Figure 2, there may be seen a cross-section of tube 100, with cap 3 connected by rigid beam 158 to the split tube 202. Behind cap 3 (into the paper) is understood to be cap 4 connected by compliant actuator (flexible beam 160) to the main rigid beam 201, and providing rigid beam 156 overlapping but not fixed to cap 3. If a person presses on cap 3 in Figure 6B (which doesn't happen in normal flute play, but is described here to explain the interactions), only cap 3 closes to cover and seal hole 103, while cap 4 and its overlapping beam 156 remain biased by flexible beam 160 to the open position.

[0064] Referring to Figures 7A and B, viewed generally along the line 7-7 in Figure 2, there may be seen a cross-section of tube 100, with cap 4 connected by flexible beam 160 to main rigid beam 201. In front of cap 4 (out from the paper) is understood to be cap 3 connected by its rigid beam 158 to the split tube 202. When a person presses on cap 4 in Figure 7B (as normally happens in normal flute play),

both cap 4 and cap 3 close to cover and seal their respective holes, because overlapping beam 156 pushes cap 3 down as well.

[0065] C. See especially Figures 1, 8, 9A, and 9B. Pressing cap 5 closes valve V5 and also valve V7. Pressing cap 5 closes cap 7 because they are rigidly attached to each other by a rigid beam 162. Each of cap 5 and cap 7 is attached to the main rigid beam 201 by a flexible beam 164, 166, wherein said flexible beams bias cap 5 and cap 7 into open positions distanced slightly from the outer surface of the tube 100, and, especially, from their respective holes 105, 107 to open valves V5, V7.

[0066] Referring to Figures 9A and 9B, viewed generally along the line 9-9 in Figure 8, there may be seen a cross-section of tube 100, with cap 5 connected by compliant actuator (flexible beam 164) to main rigid beam 201. Behind cap 5 (into the paper) is understood to be cap 7 connected by compliant actuator (flexible beam 166) to the main rigid beam 201, and rigidly linked to cap 5 by rigid beam 160. When the operator presses on cap 5 in Figure 9B, both cap 5 and cap 7 move down to cover their respective holes 105, 107.

[0067] D. See especially Figures 1, 8, 10A and 10B. Pressing lever 6 opens cap 17 by means of a flexural pivot 170, wherein downward force upon lever 6 pivots cap 17 away from the outer surface of the tube 100, and, hence, away from the hole 117 to open valve V17, by means of said flexural pivot 170 being deflected open. The flexural pivot 170 may comprise arm 171 that attaches to cap 17, and an arm 172 that extends from arm 171 to an anchor point (preferably main rigid beam 201), wherein lever 6 extends from near the connection of arm 171 to arm 172. Lever 6 is of such rigidity that pressing lever 6 serves to open up cap 17 by flexing/pivoting of arm 171 rather than just bending lever 6; lever 6 pivots, in effect, on or by means of flexural pivot 170. The combination of lever 7 and flexural pivot 170 may extend part way around the circumference of the tube, thus, opening a valve cap (17) that is, for example,  $1/4 - 3/4$  of the way (90 – 270 degrees) or more preferably  $1/2 - 3/4$  of the way (180 – 270 degrees) around the tube 100 relative to the

location of the finger-contact end of lever 6. The end of lever 6 that is pressed by the operator may also be called the “finger-contact end” of the lever or a “key.”

[0068] Referring to Figures 10 A and B, viewed generally along the line 10 - 10 in Figure 8, there may be seen a cross-section of tube 100, with lever 6 connecting to flexural pivot 170, which extends to cap 17. Pressing down on lever 6 in Figure 10B, causes cap 17 to open at a significant distance around the tube 100. Note that, lever 6 is placed over cap 7 but does not obstruct operation of cap 7 because the operator typically presses only on cap 5 to operate cap 7 for closing of valve V7.

[0069] E. See especially Figures 1, 8, 11A, 11B, 12A and 12B and 24. Pressing cap 9 closes valve V9 and also valve V8 and valve V3 simultaneously. Pressing cap 9 closes cap 8 by means of rigid beam 174 that is attached (fixed) to cap 9 and extends to overlap across at least a part of cap 8. When cap 9 is depressed by a finger, the beam 174 forces cap 8 down as well. The beam 174 is not attached to cap 8, in order to allow cap 8 to move independently of cap 9 when cap 8 is depressed by other means than cap 9 being depressed. Cap 9 is attached to the main rigid beam 201 by a flexible beam 175, which biases cap 9 into an open position (valve V9 open). Cap 8 is biased into an open position (open valve V8) by rigid beam 181 being fixed to unsplit portion 204 of split tube 202. Cap 9 is connected to unsplit portion 206 of the split tube 202 (between caps 4 and 5) by means of a clutch system, whereby rigid beam 174 operatively connects to rigid beam 176 at clutch 178, and rigid beam 176 is fixed at rigid tab 177 to unsplit portion 206. Thus, when cap 9 is pressed by a finger, the force is transferred to tab 177, which rotates unsplit portion 206, which in turn actuates cap 3 to close via the rigid beam 158 connecting unsplit portion 206 to cap 3. Therefore, at the same time the finger presses on cap 9 and both cap 9 and cap 8 close, cap 3 also closes because of a rigid beam 158 attached to the split tube in its unsplit section. Note that, at clutch 178, beam 174 can push down beam 176, but, beam 176 (being overlapped by, but unattached to, beam 178) can move down independently away from beam 174, so that, when cap 3 is pressed, the clutch is disconnected and cap 9 does not close. Further, when cap 3

is depressed by a finger, it does not cause any other caps/valves to be depressed/closed, as pressing of cap 3 causes its unsplit portion 206 of the tube 201 to rotate, but, due to clutches 178 (and also clutches 182 and 198), pressing cap 3 does not link said pressing of cap 3 to movement of caps 8, 9, 10, 11, or 13.

[0070] Referring to Figures 11A and B, viewed generally along the line 11 - 11 in Figure 8, there may be seen a cross-section of tube 100, with cap 8 connected by a rigid beam 181 to the unsplit portion 204 of split tube 202. Behind cap 8 (into the paper) is understood to be cap 9 connected by compliant actuator (flexible beam 175) to the main rigid beam 201 and providing rigid beam 174 that is overlapping but not fixed to cap 8. If a person presses on cap 8 in Figure 11A (which doesn't normally happen in normal flute play, but is described here to explain the interactions), only cap 8 closes to cover and seal hole 108, while cap 9 and its overlapping beam 174 remain biased by flexible beam 175 to the open position.

[0071] Referring to Figures 12A and 12B, viewed generally along line 12 - 12 in Figure 8, cap 9 is connected by flexible beam 175 to main rigid beam 201. In front of cap 9 (out from the paper) is understood to be cap 8 connected by its rigid beam 181 to the unsplit portion 204 of split tube 202. When a person presses on cap 9 in Figure 12B (as normally happens in normal flute play), both cap 9 and cap 8 close to cover and seal their respective holes, because overlapping beam 174 pushes cap 8 down as well. Cap 3 is not shown in Figures 12A and 12B, but it will be understood from the above discussions that cap 3 is closed via clutch 178, beam 176, and tab 177, wherein beams 174 and 176 are shown in cross-section in Figures 12A and B, and wherein clutch 178 is shown by the contact of beam 174 down against beam 176.

[0072] F. See especially Figures 1, 2, 13, 4A and 4B. Pressing rigid lever 10 opens valve V15. Lever 10, which is not located over any hole and which has a reduced-size finger-contact member at its end, is operatively connected to cap 15, by means of lever 10 and cap 15 being connected to opposite ends of a rigid hollow tube 190 that is received around, and rotates coaxially around, a rigid rod 191. Depressing lever 10 rotates hollow tube 190, which carries rigid arm 193 and

cap 15 with it to open valve V15. As a means to bias lever 10 to pivot into a closed position (that is, wherein valve cap 15 is closed), a generally C-shaped resilient member/flexural pivot member 194 is connected to the main rigid beam 201 and presses outwards/upwards against lever 10. Pressing lever 10 causes member 194 to deflect (lever 10, in effect, pivots on or by means of member 194) and allows tube 190 to open cap 15 via rigid arm 193. The end of lever 10 that is pressed by the operator may also be called the “finger-contact end” of the lever or a “key.”

[0073] G. See especially Figures 1, 13, 14A and 14B, and 26. Pressing cap 11 closes cap 11 and also cap 8 to close valve V11 and valve V8. Cap 11 is attached to the main rigid beam 201 by a flexible beam 180, which biases cap 11 into an open position. Cap 11 further utilizes a clutch 182 wherein the cap 11, or a beam/extension protruding from the cap 11, engages a rigid beam 186 attached to the split tube 210 in its unsplit portion 204 near cap 11. When the clutch 182 applies a downward force to the rigid beam 186, the split tube deflects at its slits 203, 205 and its unsplit section 204 rotates itself and also cap 8 attached to the unsplit section 204 by means of rigid beam 181. The rotation of the unsplit portion 204 of the split tube 202 closes cap 8. The end of lever 11 that is pressed by the operator may also be called the “finger-contact end” of the lever or a “key.”

[0074] H. See especially Figures 1, 2, 13, 3A and 3B. Pressing rigid lever 12 opens valve V14, by lifting cap 14. Lever 12 and cap 14 are attached opposite ends of rigid rod 191 which is free to rotate inside tube 190. The rigid rod 191 may be supported on the tube 100 by rotatably extending through two rigid posts C6', wherein the tube 190 is also retained between said posts. Said tube 190 and said rod 191 allow indirect, remote operation of cap 14, by extending a substantial way along the flute tube 100, from near caps 11 and 13 to beyond cap 1. The rigid rod 191 is received within the hollow tube 190 substantially all the way from lever 10 to cap 15 to support that interaction and to conserve space. “C” shaped member/flexural pivot 196 resiliently presses against lever 10 to bias lever 10 into a raised position that keeps cap 15 closed. Pressing lever 10 causes member

196 to deflect and open cap 15; lever 12, in effect, pivots on or by means of member 196. It should be noted that the rod and tube system may be connected to the flute by means of posts C6' removeably connecting to the tube 100, but it is preferred that the rod and tube system be connected to other structure of actuator system 1001 to make the actuator system for caps 14 and 15 a part of a single unit main module 1001.

[0075] I. See especially Figures 1, 8, 13, 14A and 14B, and 25. Pressing cap 13 closes valve V13 and also valve V8. Cap 13 is attached to the main rigid beam 201 by a flexible beam 195, which biases cap 13 into an open position. Cap 13 further utilizes a clutch 192 wherein the cap 13, or a beam/extension protruding from the cap 13, engages a rigid beam 196 attached to the split tube 202 in its unsplit portion 204 near cap 13. When the clutch 192 applies a downward force to the rigid beam 196, the split tube deflects at its slits 203, 205 and its unsplit section 204 rotates itself and also cap 8 attached to the unsplit section 204 by means of rigid beam 181. The rotation of the unsplit portion 204 of the split tube 202 closes cap 8.

End Joint Module Actuator System 1002, located on end joint E:

[0076] J. See especially Figures 1, 16, and 17A and 17B. Pressing lever 18 distances cap 23 from the end joint tube 300 to open valve V23 on the end joint E. Cap 23 is normally kept closed by a "C-shaped" flexural pivot 302 that has a portion fixed to the lever 18, and a portion fixed to the end joint main rigid beam 304. The lever 18 extends part way around the circumference of end joint tube 300 to connect to cap 23.

[0077] K. See especially Figures 1, 16, and 27. Pressing lever 20 (which has no hole under it) closes cap 21 to close valve V21. Lever 20 and cap 21 are rigidly attached to each other. Each of lever 20 and cap 21 is attached to the end joint main rigid beam 304 by a flexible beam 308, 310, wherein beams 308, 310 bias lever 20 and cap 21 into open positions, respectively.

[0078] L. See especially Figures 1, 16, 18A and 18B, 22 (split tube), and 28. Pressing lever 19 closes valve V21 and valve V22, by closing cap 21 and cap 22 over opening 121 and 122, respectively. Lever 19 extends over ("overlaps") a portion of lever 20, or is sized and located, so that pressing on lever 19 also forces lever 20 down, as in item K above, to close cap 21. Lever 19 is rigidly attached to end joint split tube 305 in its unsplit section between slit 306 and slit 307, and cap 22 is also rigidly attached to split tube 305 in its unsplit section by means of rigid beam 312. Thus, split tube 305 biases both lever 19 and cap 22 into open positions. When lever 19 is pressed, however, the sections of the tube 305 having slits 306, 307 deflect and the unsplit section rotates, carrying cap 22 with it, and thus closing cap 22. Note that, in the cross-sections of Figures 18A and 18B, viewed along line 18-18 in Figures 16, the connection of lever 20 to the main rigid beam 304 is not shown, but is understood to be by a flexible beam 308 that is visible in Figure 16. Note that end joint main beam 304 and end joint split tube 305 may be connected to the releasable connectors on end joint tube 300 by posts C4', C5'.

Modular Section for Cap 16, located on tube 100:

[0079] M. See Figure 29. Pressing cap 16 closes valve V16. Cap 16 is attached to a "C-shaped" flexural pivot 199 that biases cap 16 to an open position. Pressing the cap 16 deflects the "C-shaped" pivot 199 and closes cap 16.

[0080] From the above description and the drawings, it may be seen that the preferred embodiments comprises both direct and indirect actuators. Each of these two general types of actuators may be used, or linked to other actuators, for closing one or more valves.

[0081] The direct actuators may be described as comprising direction and location of motion of a cap (or other finger-contact member) that is the same as the operator motion. In the preferred flute embodiment, the direct actuators are portrayed as compliant beams that allow closing of normally-open valves by pressing on the cap of the valve. The compliant beams are portrayed as convex-

curved strap-shaped members, when there is no force being applied, but other direct actuators may be used, such as concave-curved or non-curved flexible beams, straps, bars, etc.

[0082] The indirect actuators may comprise systems wherein pressing a finger-contact member (a key, cap, lever end, for example) actuates an adjacent or nearby cap to close or open a valve. Examples of may include a rigid lever connecting or overlapping between two adjacent/neighboring caps; or a lever curving around the flute (circumferentially distanced) to reach a valve that is not in an axial line with the majority of the valves.

[0083] Other indirect actuators may be called “remote,” as they comprise systems wherein pressing a finger-contact member (a key, cap, lever end, for example) actuates a significantly-axially-distanced cap to close or open a valve. Such remote indirect actuators may comprise pressing a lever’s finger-contact end to rotate a rigid bar or tube to lift normally-closed caps that extend away from the bar/tube in a direction from the bar/tube opposite from the finger-contact end of the lever. It may be noted that, if the caps were to extend away from the rigid bar/tube in the same direction as the lever finger-contact end, then pressing said finger-contact end would lower normally-open caps to close valves.

[0084] It may also be noted that many actuators will typically be biased by, and pivot on/by means of, a flexural pivot member, such as the “C-shaped resilient members” or “flexural pivots” illustrated herein or other flexural pivot members not drawn. “Flexural pivot” and “flexural pivot member” are broad terms that mean various shapes and designs of flexible, compliant, bendable, and preferably resilient, members that allow pivoting/rotation of said lever relative to a structure by virtue of the flexing, bending, or folding of the pivot member. In this document, the term “flexural pivot member” typically refers to such a member that has arms or portions for accommodating a first class lever by connecting the lever to an anchoring structure and allowing the lever to pivot relative to said anchoring structure by said flexing, bending or folding, and wherein the preferred flexural pivot member serves

as the fulcrum located between the input force and the output force in the operations of the actuator system. The finger-contact member that moves the lever in such embodiments may be an end of the lever or a finger-pad or other member that is connected to the lever.

[0085] It may be noted that flexural pivots may be designed to act as direct actuators, in place of the compliant beams, but such flexural pivots may be more expensive, and complex and may take up more space, than the preferred compliant beams that extend preferably directly and solely from an anchoring structure (such as beam 201) to their respective caps.

[0086] Remote indirect actuators may also include elongated compliant hinges, such as torsional hinges, that preferably may provide both compliant rotation (via flexing, bending, or folding) and bias for more than a single cap and/or to levers that are located a significant axial distance from the hinge along the length of the wind instrument. Similarly to the comment above regarding rigid bar/tubes, the caps being acted upon by a torsional or other elongated compliant hinge may be raised (from a normally-closed position) or lowered (from a normally-open position) depending upon what side of the hinge the caps are compared to the lever or other member causing the hinge rotation.

[0087] In the preferred direct and indirect actuators, the actuator members (compliant beams, flexural pivots, and compliant hinges) are anchored to a rigid beam or to posts to form a single module, wherein the entire module of finger-contact members, actuators, and caps for many valves (preferably 10 or more) is disconnectable from the wind instrument via disconnection of just a few connectors/posts (preferably 2 – 4). Alternatively, or in smaller modules, actuators may be anchored directly to the wind instrument tube (see Figures 33A and B, for example).

[0088] Preferably, the actuator systems of the invention do not comprise rigid links connected at movable joints. Preferably, the actuator systems of the

invention do not comprise the wire springs that conventionally extend short distances along portions of the rigid link and joint system of the traditional Boehm apparatus. If deemed necessary in some embodiments, however, some rigid links connected at movable joints or other non-compliant actuators may be added. Further, it should be noted that additional structure, other than what is shown in the drawings may be included in wind instruments according to the invention, including structure that is desirable in piccolo, clarinet, oboe, bassoon, and saxophone instruments, for example.

[0089] Although this invention has been described above and in the drawings with reference to particular means, materials, and embodiments, it is to be understood that the invention is not limited to these disclosed particulars, but extends instead to all equivalents within the scope of the following claims.

## CLAIMS

I claim:

1. A wind instrument comprising:  
at least one tube housing a resonating column of air, said at least one tube having a tube wall with an axial dimension and a circumferential dimension;  
a plurality of openings in the tube wall that connect the column of air with the surrounding air;  
an actuator system comprising caps that are each moveable into a closed position adapted to block a respective opening of said plurality of openings and moveable into an open position adapted to unblock said respective opening;  
the actuator system comprising a rigid anchor beam that is attached to said at least one tube, and compliant beams that connect multiple of said caps to said rigid anchor beam and that bias said multiple caps to open or closed positions;  
the actuator system further comprising a first finger-contact member, and a first indirect actuator that operatively connects said first finger-contact member to a first of said caps located on said at least one tube and distanced from the first finger-contact member, wherein said first indirect actuator is adapted to open or close said first cap when said first finger-contact member is pressed; and  
wherein said first indirect actuator comprises a compliant portion selected from the groups consisting of a flexural pivot member and a torsional hinge.
2. A wind instrument as in Claim 1, wherein the first cap is distanced from said first finger-contact member axially along said at least one tube.
3. A wind instrument as in Claim 1, wherein said first cap is distanced from the first finger-contact member circumferentially around said at least one tube.

4. A wind instrument as in Claim 2, wherein said compliant portion is a flexural pivot and wherein said first finger-contact member pivots on said flexural pivot and operatively connects to a rigid rotatable rod near one end of the rod and wherein said first cap is rigidly connected to the rotatable rod near an opposite end of the rod, so that, when said first finger-contact member is pressed, the rod rotates to open or close said first cap.

5. A wind instrument as in Claim 4, comprising a second finger-contact member, a second of said caps that is located on said at least one tube and distanced from said second finger-contact member;  
wherein said second finger-contact member pivots on a flexural pivot and operatively connects to a rigid rotatable tube near one end of the rotatable tube and wherein said second cap is rigidly connected to the rotatable tube near an opposite end of the rotatable tube, so that, when said second finger-contact member is pressed, the rotatable tube rotates to open or close said second cap; and  
wherein said rotatable tube has an interior passageway that receives said rotatable rod so that said rotatable tube and rotatable rod extend coaxially along said at least one tube of the wind instrument.

6. A wind instrument as in Claim 3, wherein said compliant portion is a flexural pivot; and wherein said first indirect actuator comprises a curved lever extending circumferentially around a portion of said at least one tube, that connects at one end to said first finger-contact member and connects at an opposite end to said first cap, and that pivots on said flexural pivot to open or close said first cap.

7. A wind instrument as in Claim 1, wherein said actuator system further comprises an adjacent one of said caps and a rigid beam extending between and fixed to each of said first finger-contact member and said adjacent cap, so that pressing either of said first finger-contact member and said adjacent cap closes said adjacent cap.

8. A wind instrument as in Claim 1, wherein said actuator system further comprises an adjacent one of said caps and a rigid beam fixed to said first finger-contact member and overlapping at least a part of said adjacent cap, so that pressing said first finger-contact member closes said adjacent cap and so that pressing said adjacent cap does not move said first finger-contact member.

9. A wind instrument as in Claim 7, wherein said first finger-contact member further comprises a cap that blocks an opening directly below said first finger-contact member when either of said first finger-contact member or said adjacent cap is pressed.

10. A wind instrument as in Claim 8, wherein said first finger-contact member further comprises a cap that blocks an opening directly below said first finger-contact member when said first finger-contact member is pressed.

11. A wind instrument as in Claim 1, wherein:  
said compliant portion is a torsional hinge;  
said first cap is rigidly connected to the torsional hinge;  
said first finger-contact member is connected to said rigid anchor beam by a compliant beam that biases said first finger-contact member away from said at least one tube; and  
the actuator system further comprises a rigid extension protruding from said first finger-contact member and operatively connected to said torsional hinge, so that, when said first finger-contact member is pressed, the rigid extension rotates the torsional hinge to move said first cap into an open or closed position by means of said first cap being rigidly connected to the torsional hinge.

12. A wind instrument as in Claim 11, wherein said rigid extension is operatively connected to said torsional hinge by a clutch, wherein said rigid extension contacts, but is not attached to, a tab rigidly extending from the torsional hinge, so that said rigid extension pressing on said tab rotates said hinge.

13. A wind instrument as in Claim 11, wherein said torsional hinge is axially distanced from said first finger-contact member so that multiple of said openings and multiple of said caps are located between said first finger-contact member and said torsional hinge, and wherein said rigid extension is elongated and extends axially to reach said torsional hinge.

14. A wind instrument as in Claim 11, wherein said torsional hinge comprises a split tube having an unsplit portion and a portion with a slit at each end of said non-split portion, wherein rotation force applied to said unsplit portion causes the portions with a slit to deflect to allow the unsplit portion to rotate generally on its axis.

15. A wind instrument as in Claim 1, wherein said first finger-contact member is connected to said rigid anchor beam by a compliant beam that biases said first finger-contact member to an open position, and wherein said first finger-contact member comprises a rigid extension operatively connected to a first torsional hinge that is near the first finger-contact member, and wherein said first cap is rigidly connected to said first torsional hinge, so that, when said first finger-contact member is pressed, the first torsional hinge is rotated to move said first cap into an open or closed position; and

wherein the actuator system further comprises a second finger-contact member that is near said first torsional hinge and comprises a second torsional hinge that is axially distanced from both the first and second finger-contact members, wherein said second finger-contact member comprises an elongated, second rigid extension that operatively connects to the second torsional hinge to rotate the second torsional hinge to open or close a cap rigidly that is near and connected to the second torsional hinge.

16. A wind instrument as in Claim 15, wherein each of said first and said second finger-contact members comprise a cap directly over a respective opening in said at

least one tube, so that pressing said first or said second finger-contact members closes said respective opening.

17. A wind instrument as in Claim 1, wherein said wind instrument is a flute.

18. A wind instrument as in Claim 2, wherein said wind instrument is a flute.

19. A wind instrument as in Claim 3, wherein said wind instrument is a flute.

20. A wind instrument as in Claim 1, wherein said actuator system comprises at least 10 caps and is attached to said at least one tube by three posts, and wherein said actuator system is disconnectable from said at least one tube as a single unit by detaching said three posts from the at least one tube.

21. A wind instrument as in Claim 2, wherein said actuator system comprises at least ten of said caps and is attached to said at least one tube by three posts, and wherein said actuator system is disconnectable from said at least one tube as a single unit by detaching said three posts from the at least one tube.

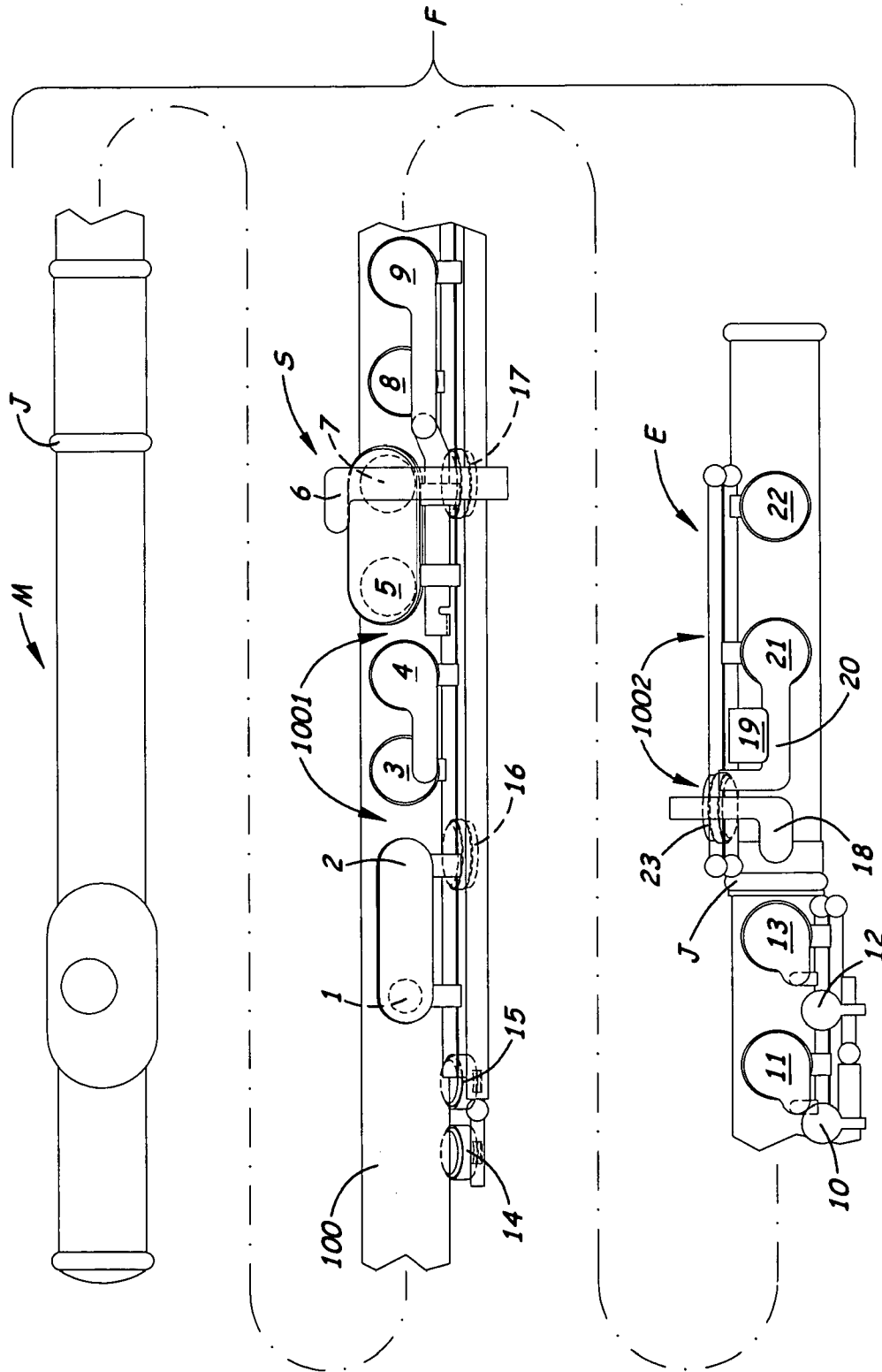
22. A wind instrument as in Claim 3, wherein said actuator system comprises at least ten of said caps and is attached to said at least one tube by three posts, and wherein said actuator system is disconnectable from said at least one tube as a single unit by detaching said three posts from the at least one tube.

23. A wind instrument as in Claim 1, wherein said compliant beams that connect multiple of said caps to said rigid anchor beam bias said multiple caps to open positions and wherein said compliant portion or the first indirect actuator biases said first cap to a closed position.

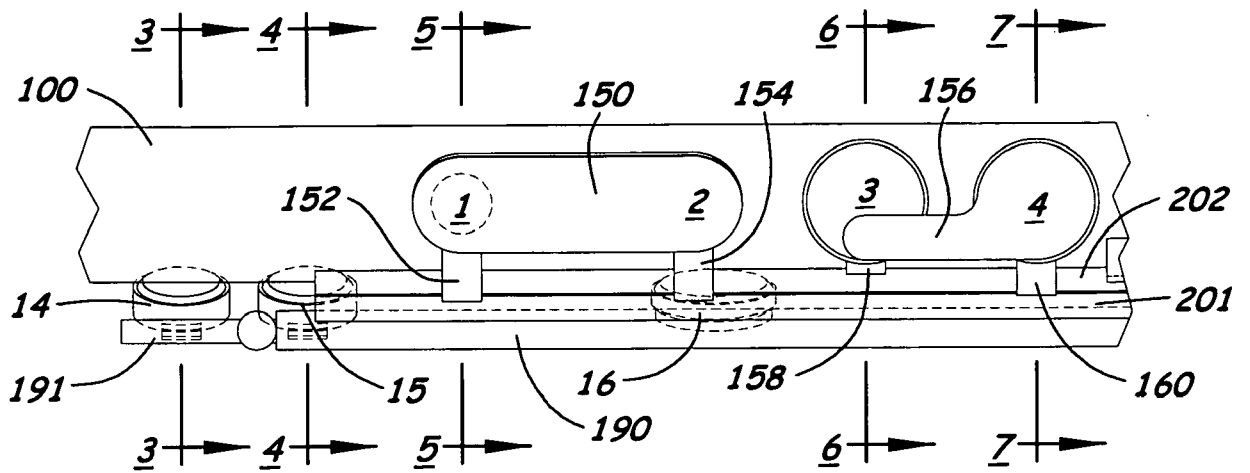
24. A wind instrument as in Claim 1, wherein each of said compliant beams that connect multiple of said caps to said rigid anchor beam have a curvature when no forces are applied against said caps.

25. A wind instrument as in Claim 1, wherein said flexural pivot is a C-shaped member.

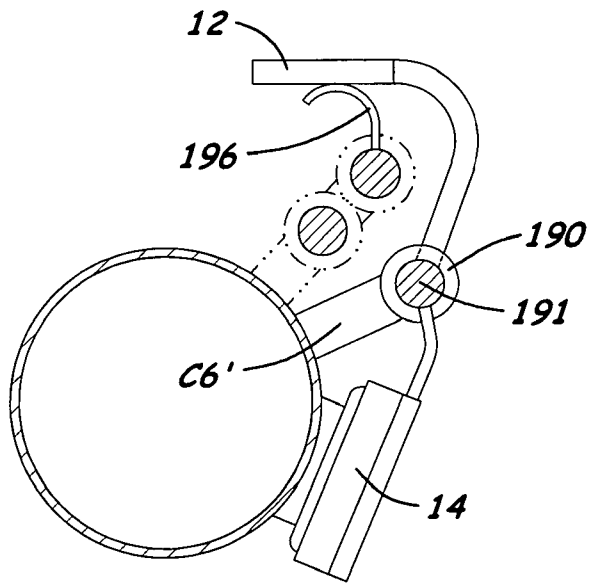
26. A wind instrument as claimed in Claim 1 wherein the first cap is normally held closed and wherein said first finger-contact member and said first indirect actuator are adapted to open said first cap when the first finger-contact member is pressed.



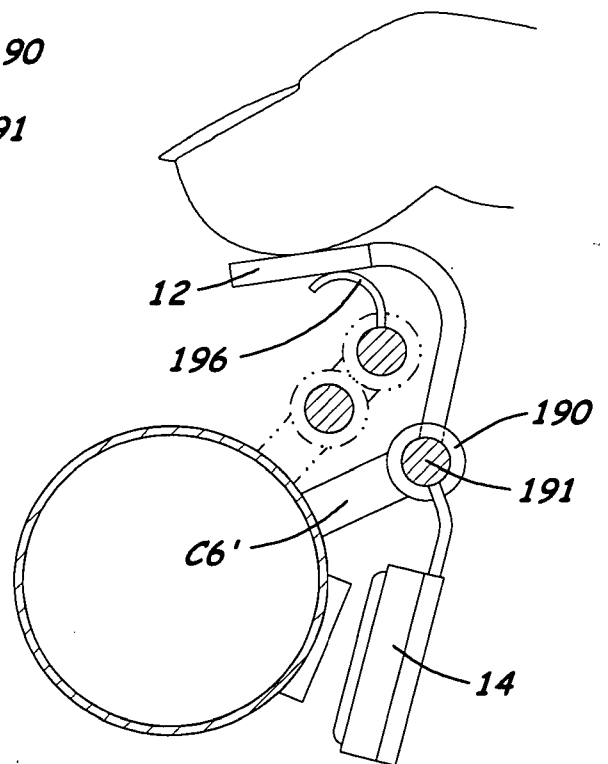
**Fig. 1**



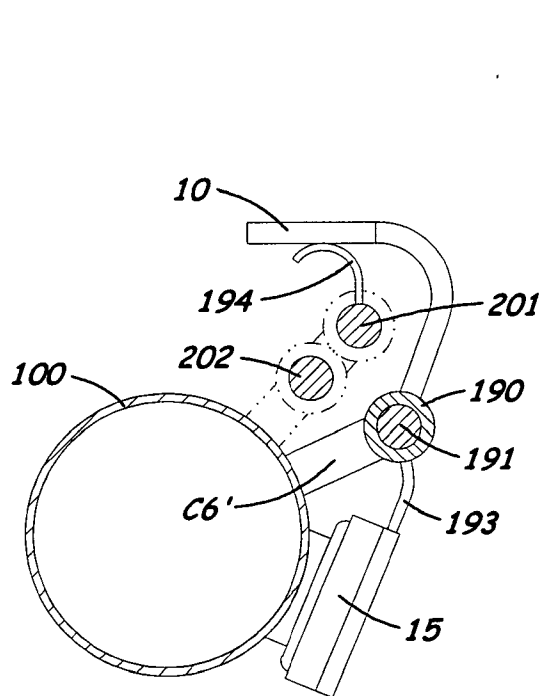
**Fig. 2**



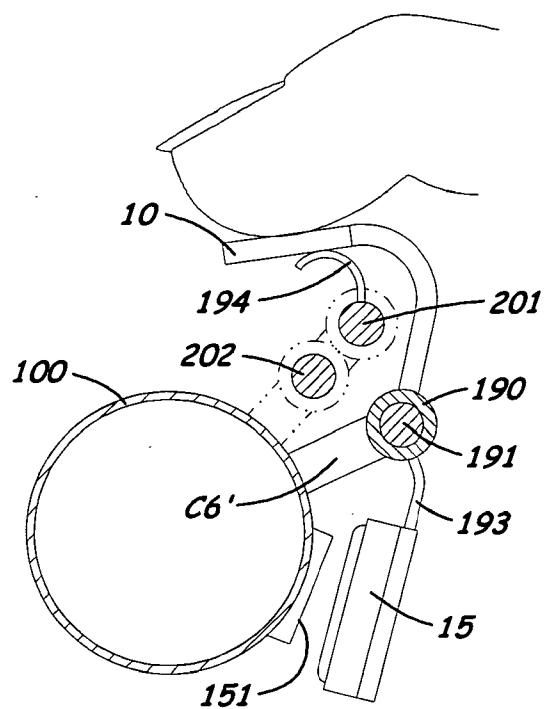
**Fig. 3A**



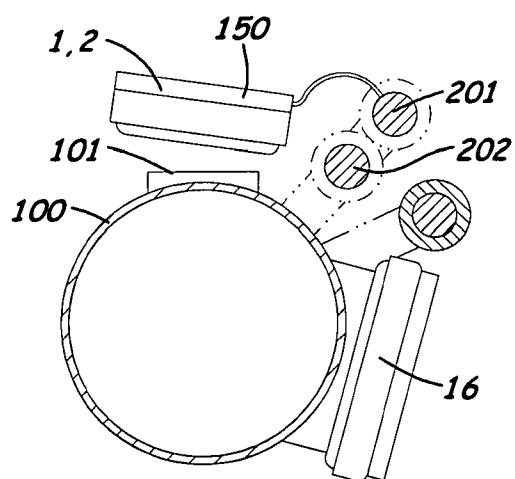
**Fig. 3B**



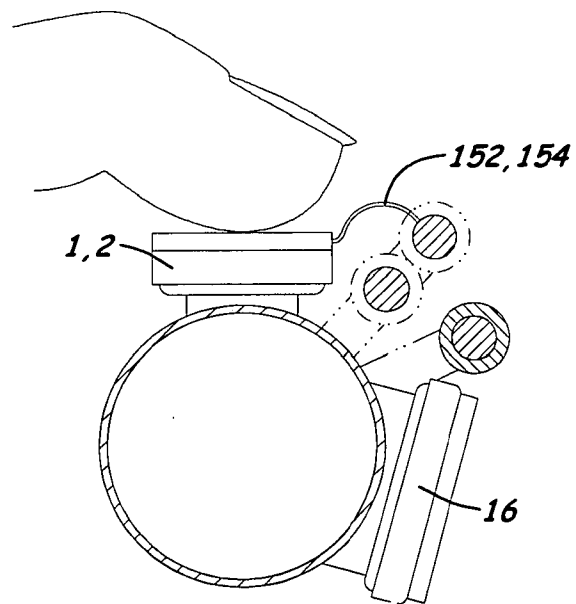
**Fig. 4A**



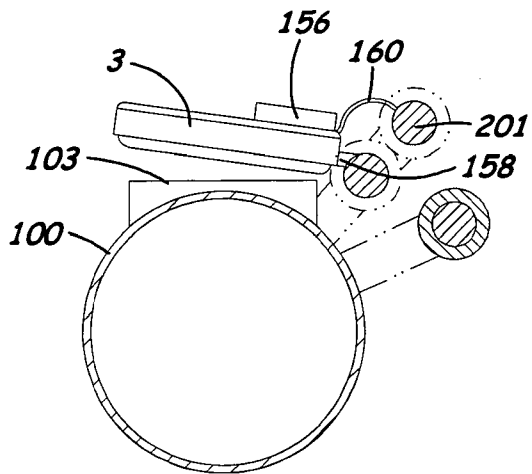
**Fig. 4B**



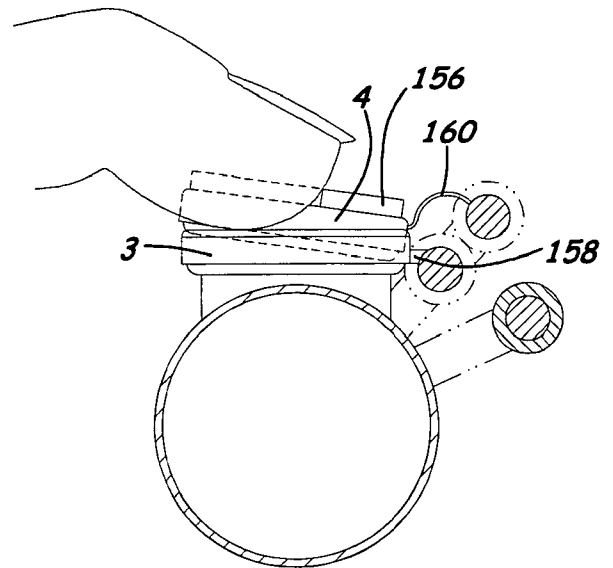
**Fig. 5A**



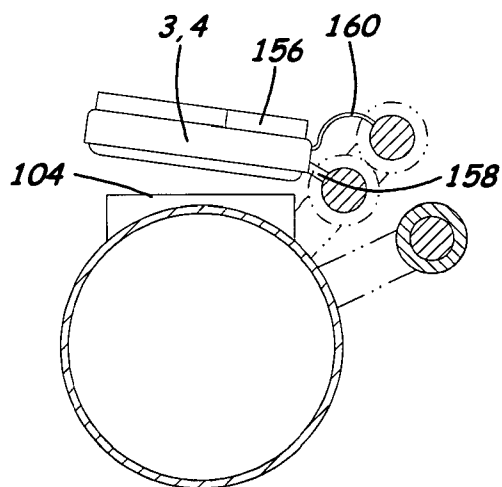
**Fig. 5B**



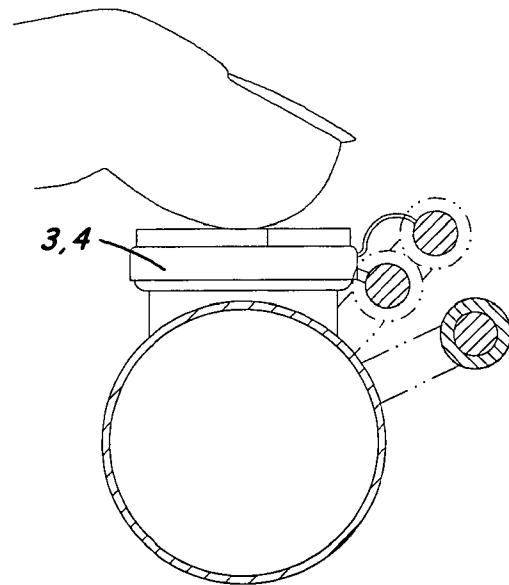
**Fig. 6A**



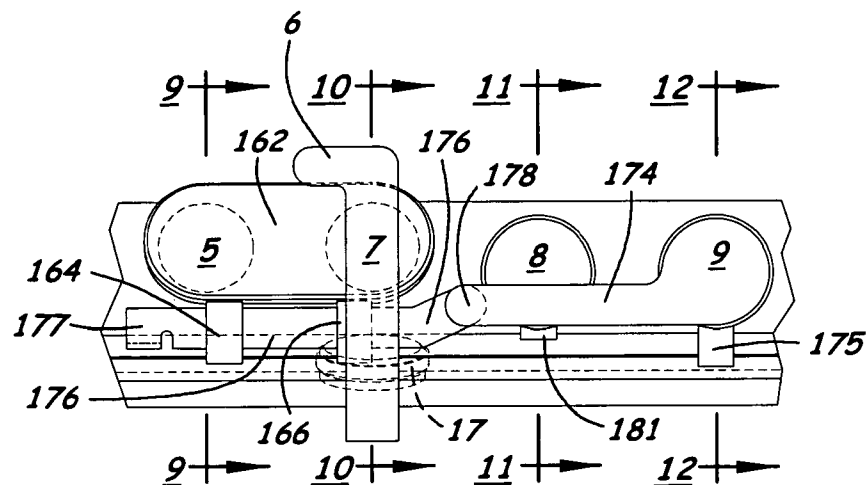
**Fig. 6B**



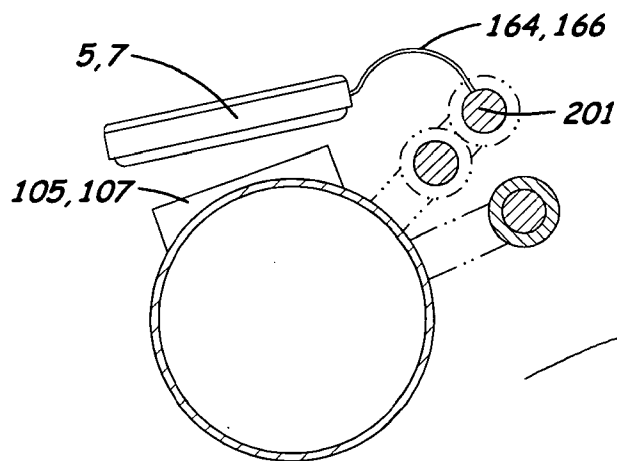
**Fig. 7A**



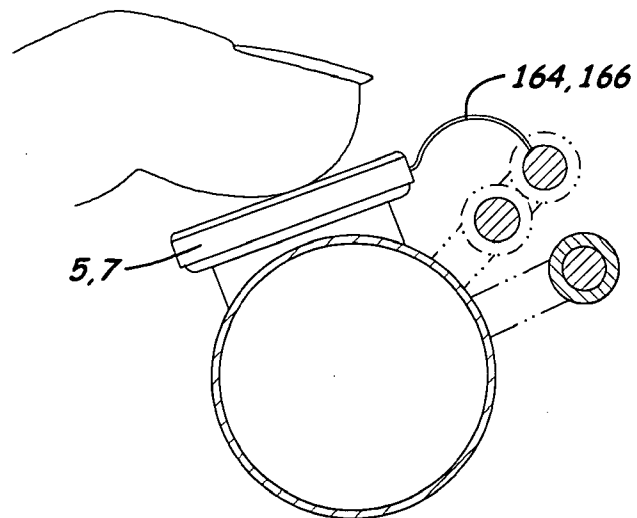
**Fig. 7B**



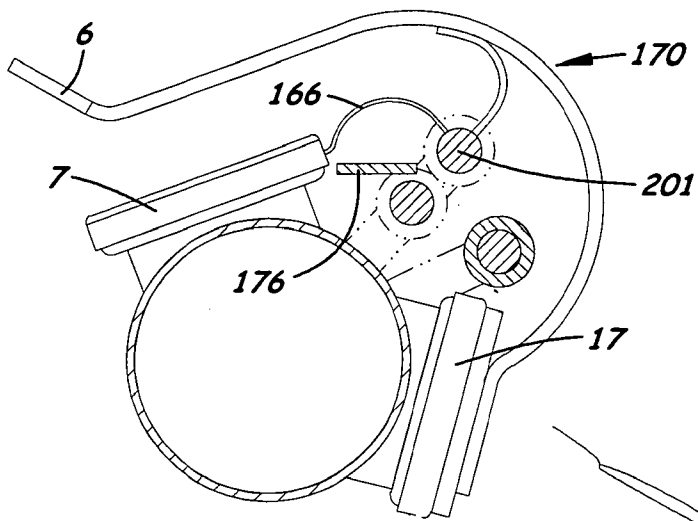
**Fig. 8**



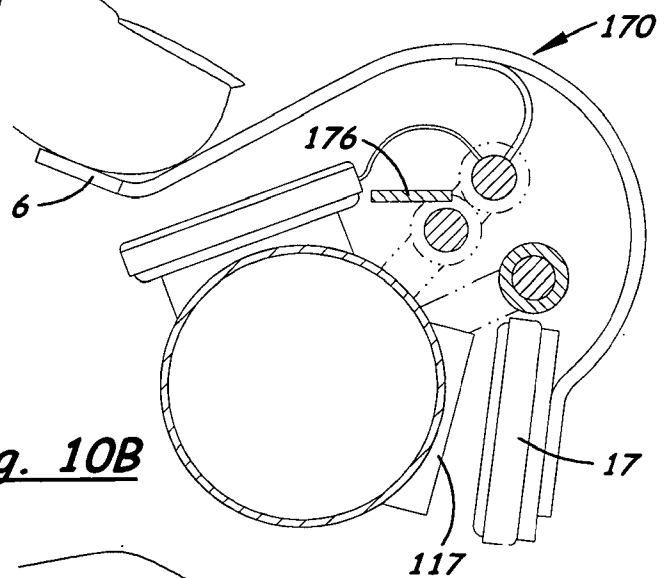
**Fig. 9A**



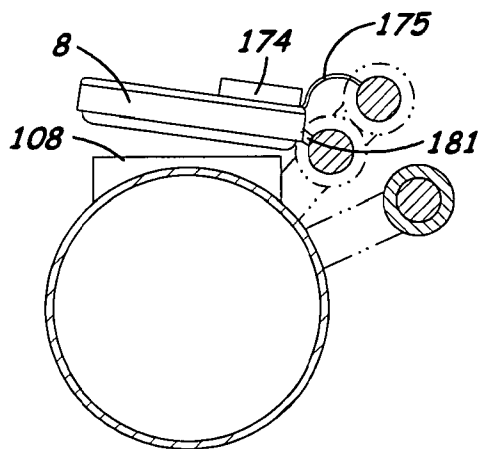
**Fig. 9B**



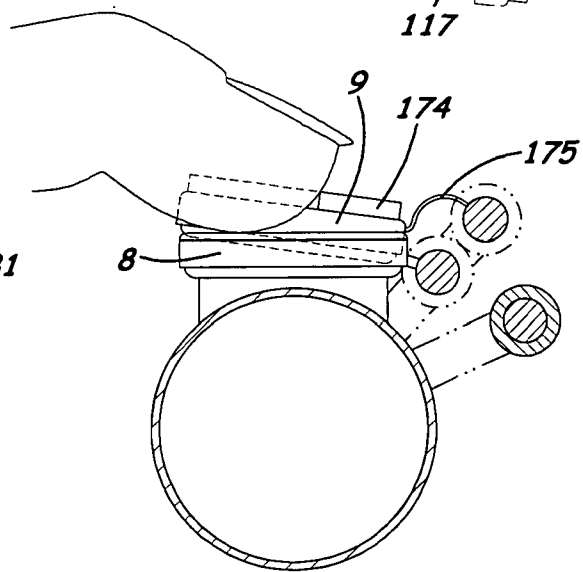
**Fig. 10A**



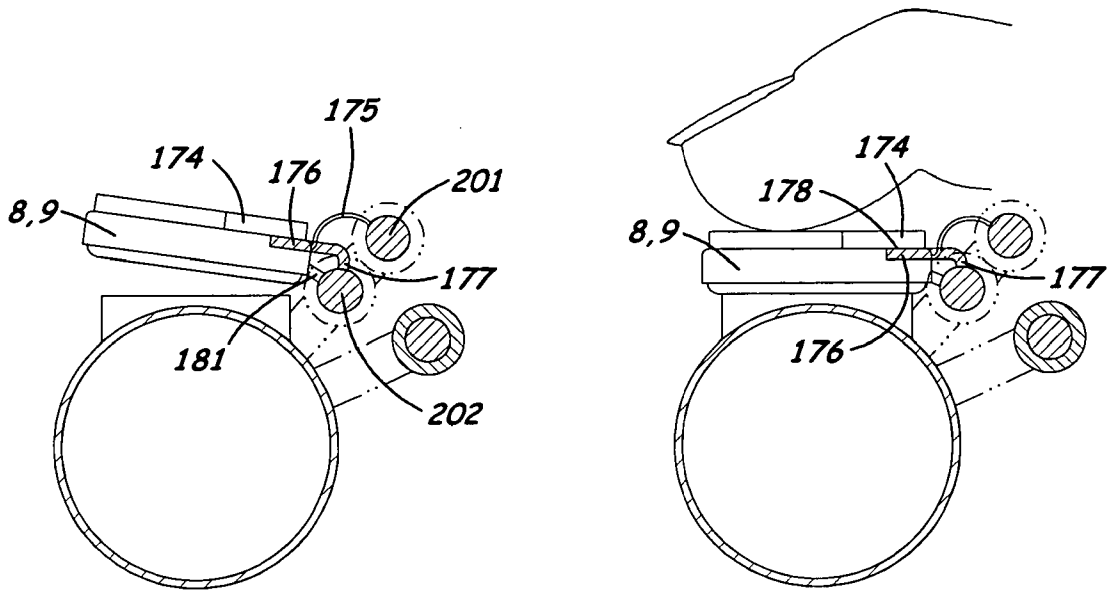
**Fig. 10B**



**Fig. 11A**

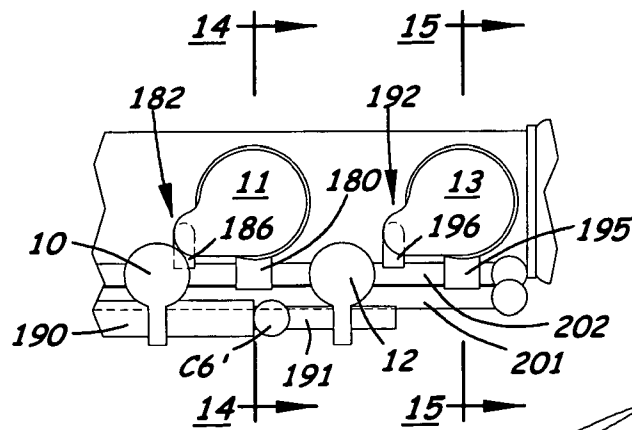


**Fig. 11B**

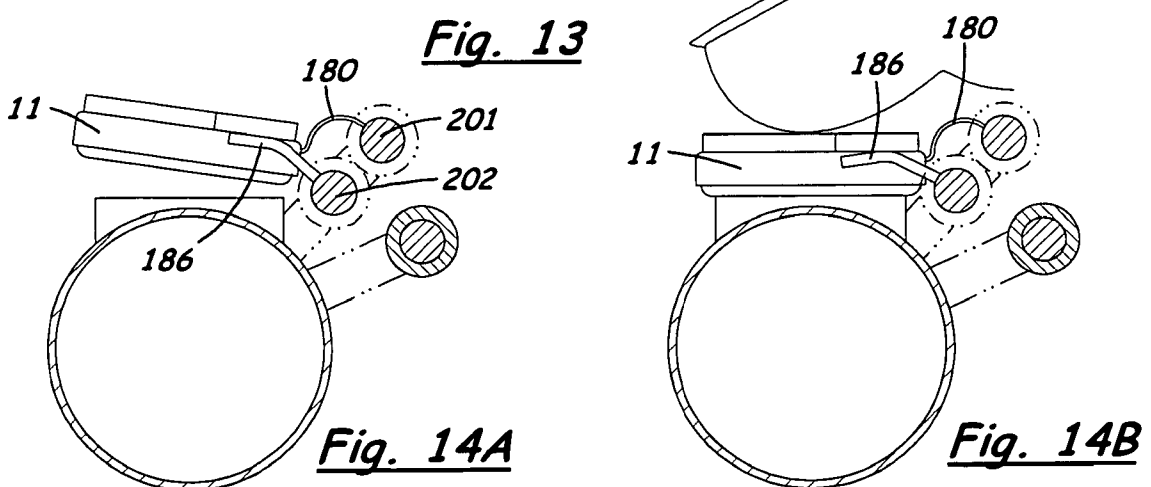


**Fig. 12A**

**Fig. 12B**



**Fig. 13**



**Fig. 14A**

**Fig. 14B**

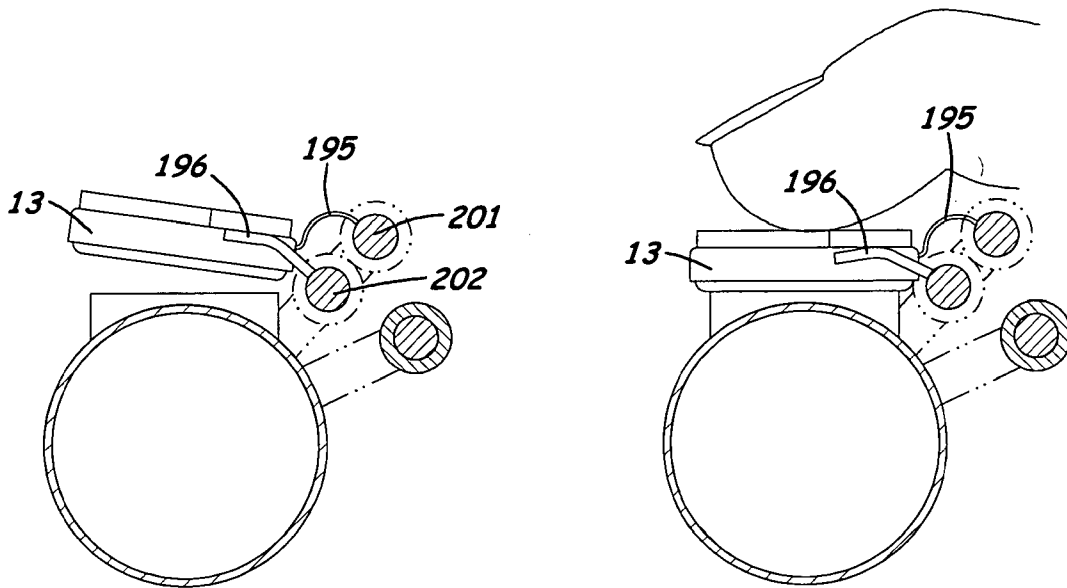


Fig. 15A

Fig. 15B

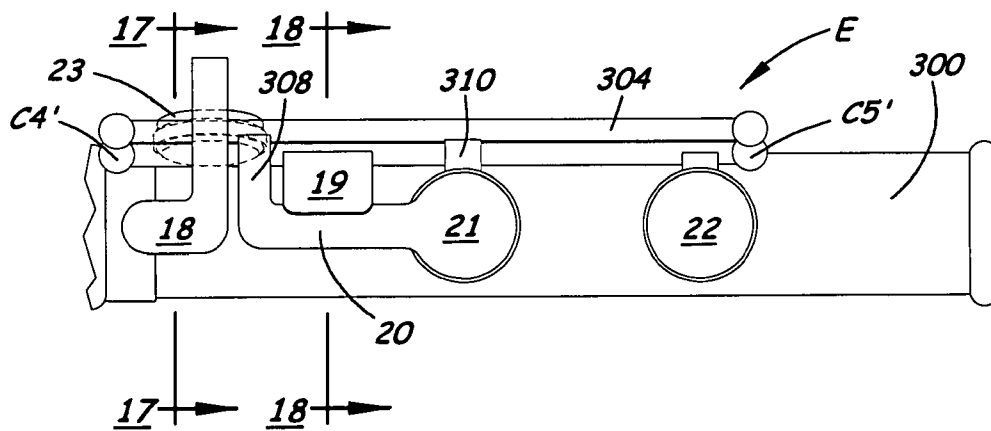
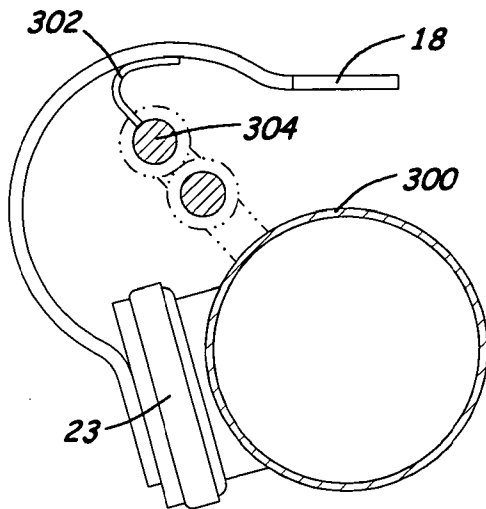
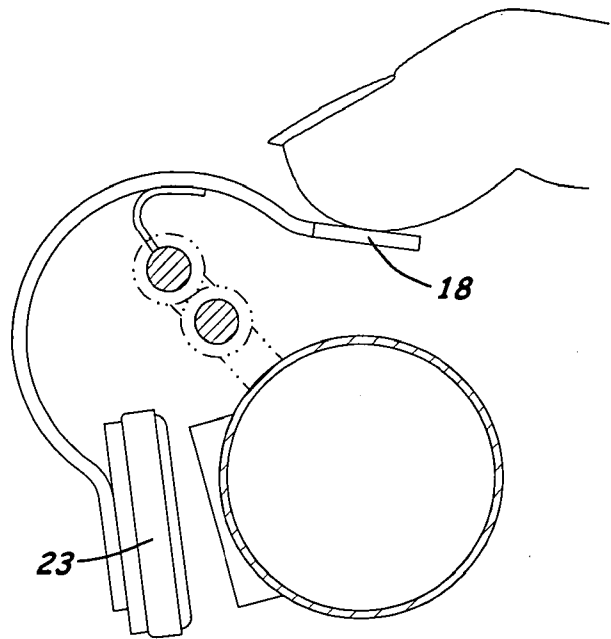


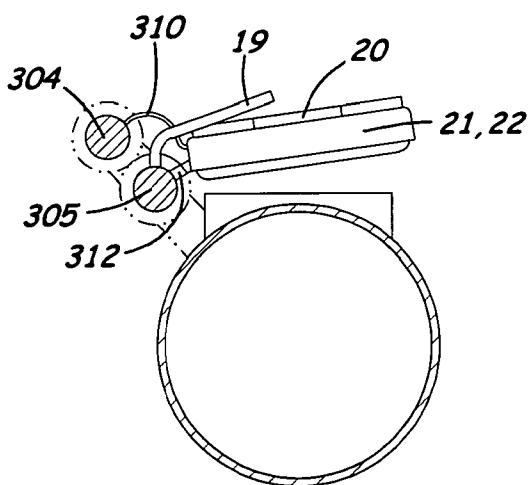
Fig. 16



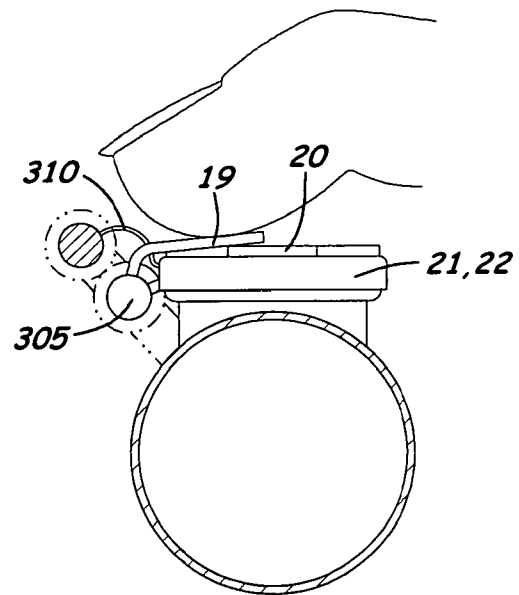
**Fig. 17A**



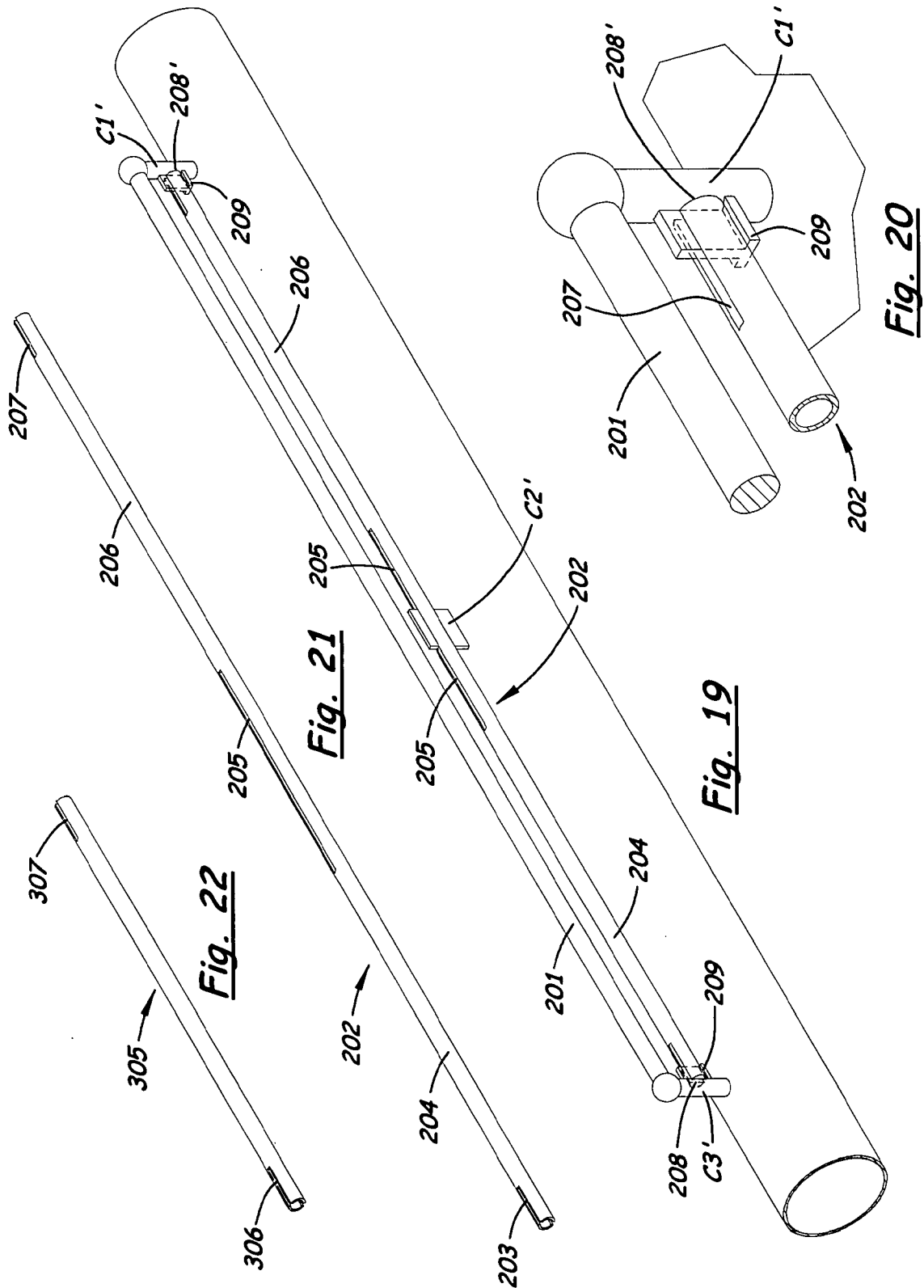
**Fig. 17B**



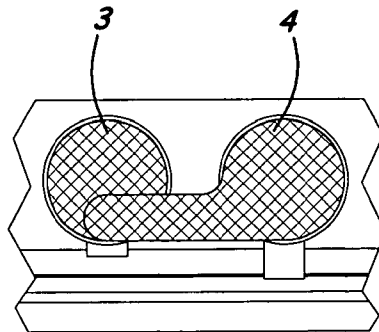
**Fig. 18A**



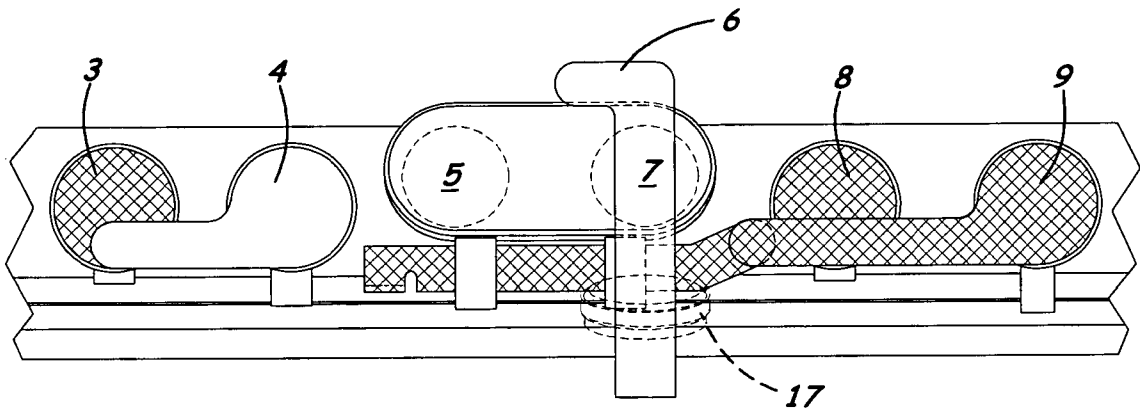
**Fig. 18B**



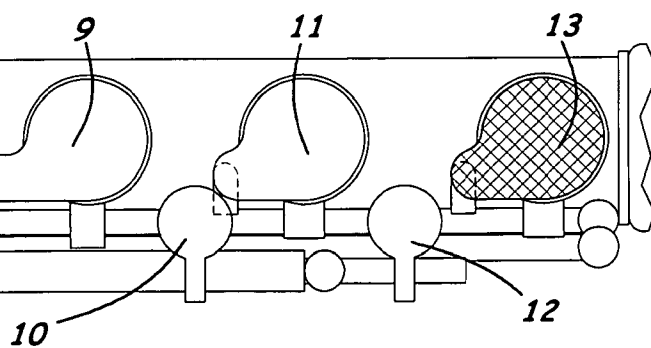
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**Fig. 23**

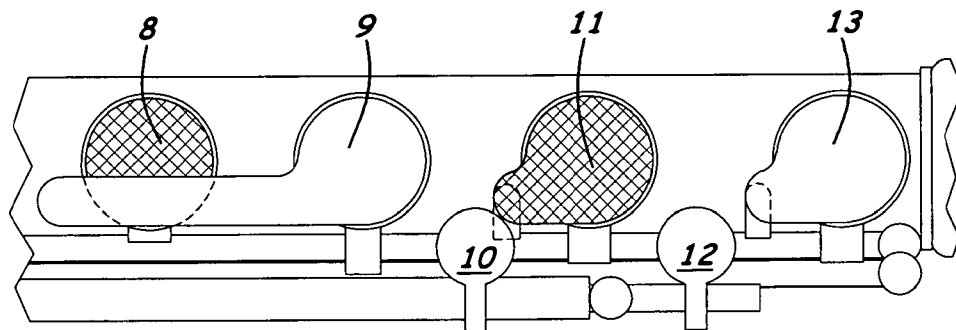


**Fig. 24**

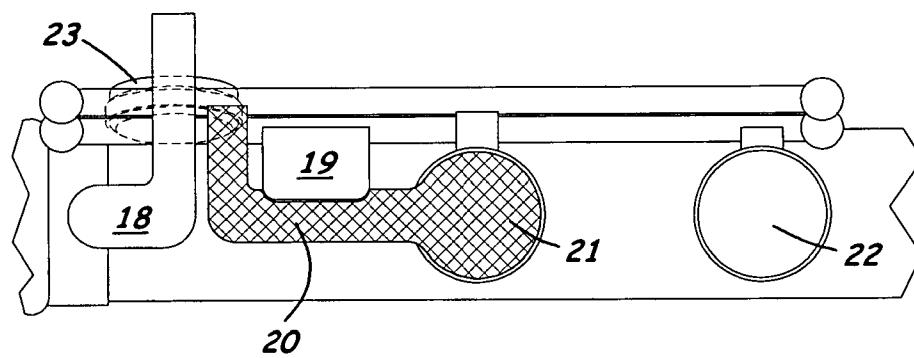


**Fig. 25**

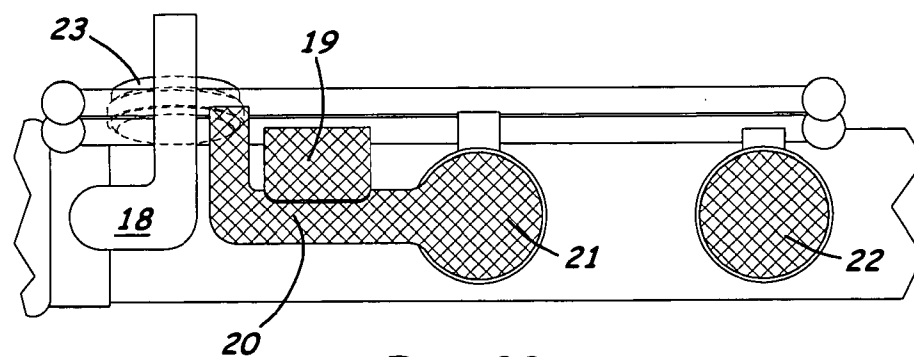
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**Fig. 26**



**Fig. 27**



**Fig. 28**

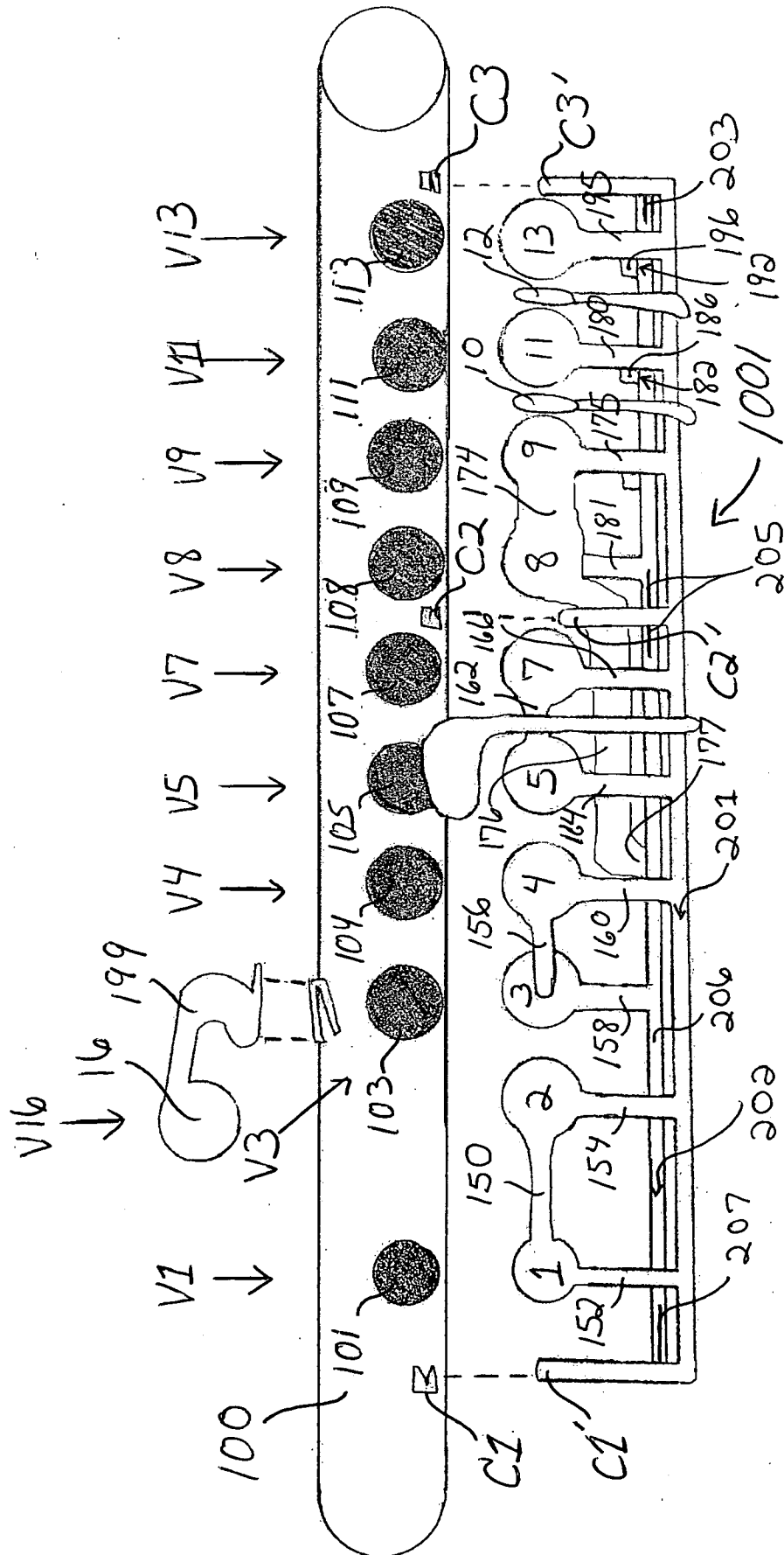
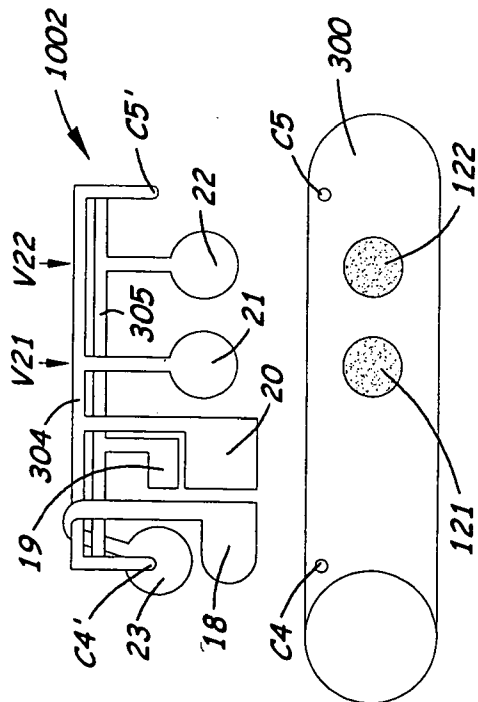
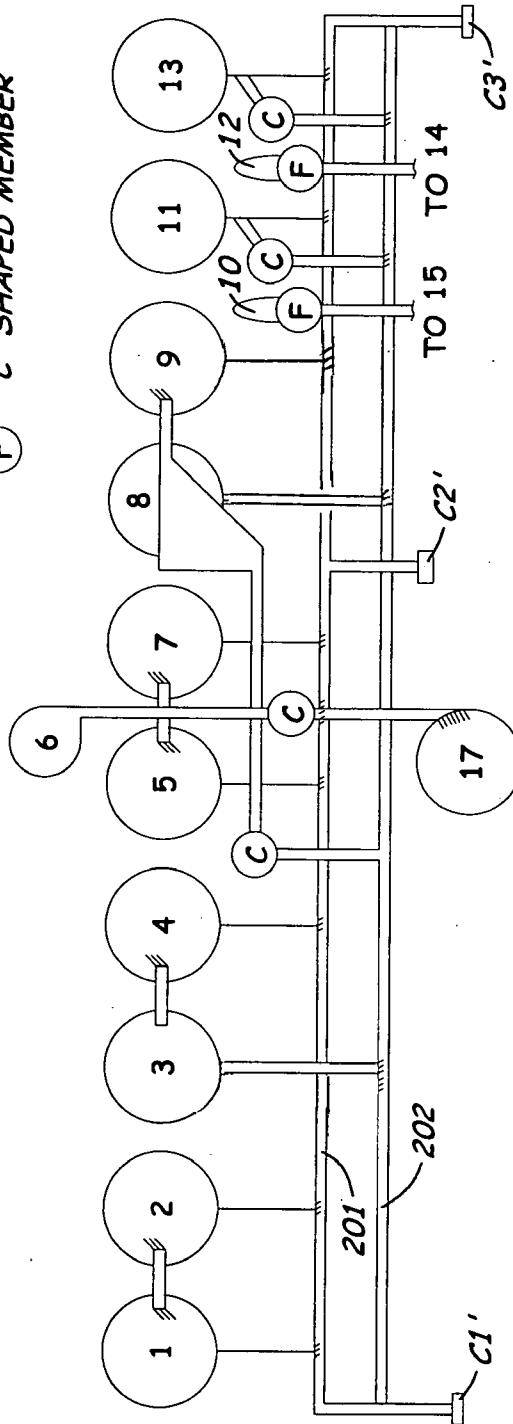


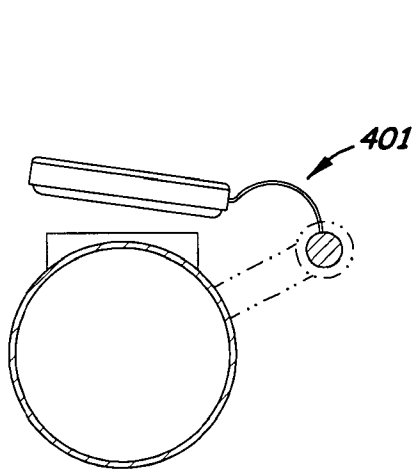
Fig. 29



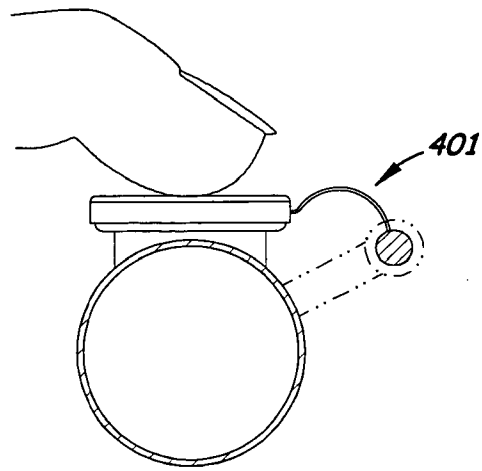
**Fig. 30**



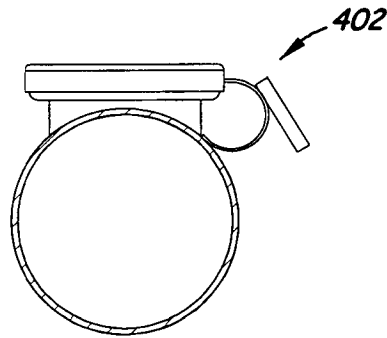
**Fig. 31**



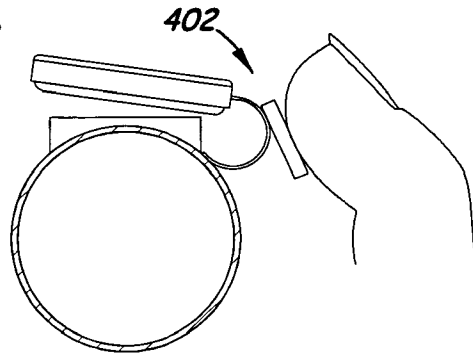
**Fig. 32A**



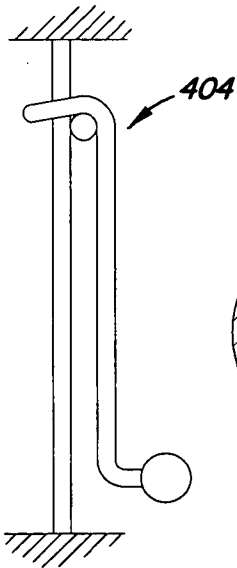
**Fig. 32B**



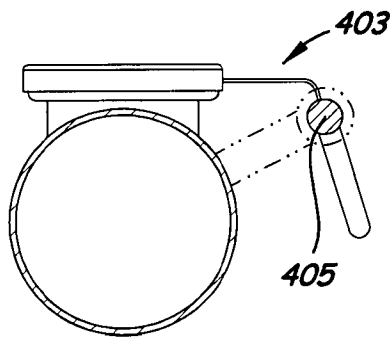
**Fig. 33A**



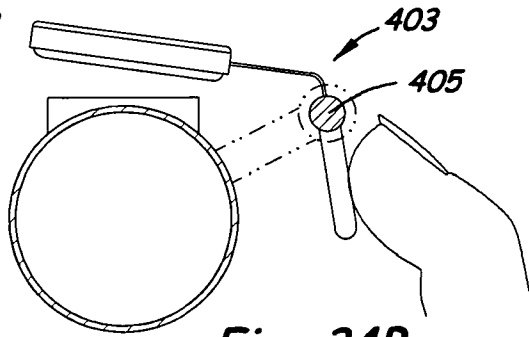
**Fig. 33B**



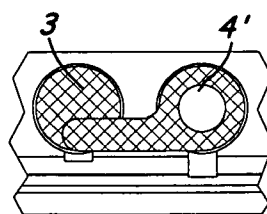
**Fig. 35**



**Fig. 34A**



**Fig. 34B**



**Fig. 36**