FIG. 1A

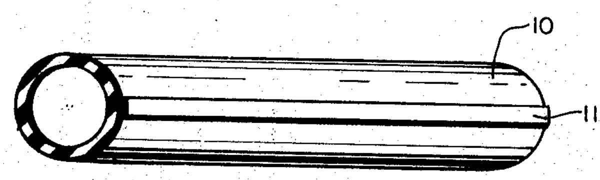


FIG. 1B

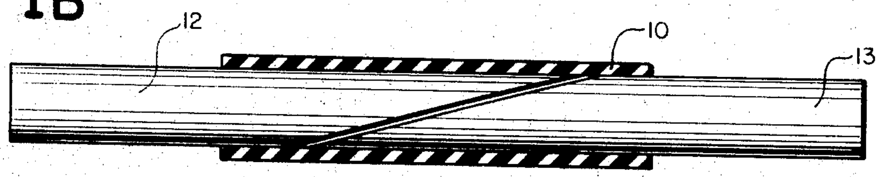


FIG. 1C

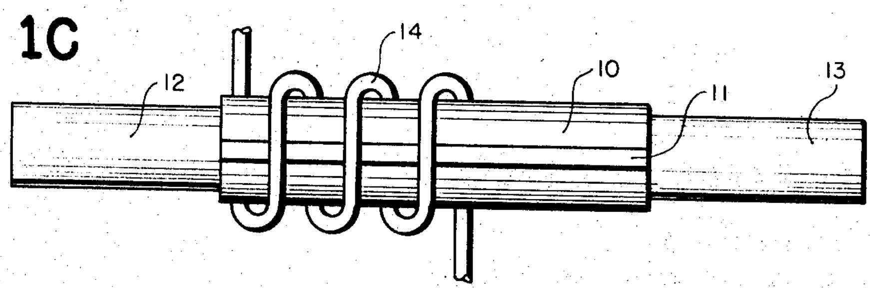
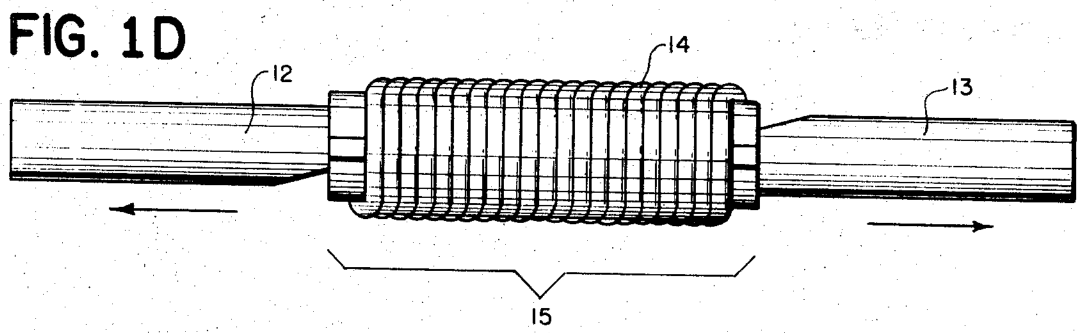


FIG. 1D



Stanley R. Rich
Inventor
by Alfred H. Rosen
Attorney

United States Patent

[11] 3,561,330

[72] Inventor Stanley R. Rich
Worcester, Mass.
[21] Appl. No. 872,456
[22] Filed Nov. 24, 1969
[45] Patented Feb. 9, 1971
[73] Assignees Stanley R. Rich
Worcester,
by mesne assignment a part interest;
Alfred H. Rosen
Newton,, by mesne assignment a part interest; Leonard L. Krasnow, Worcester, Mass., by mesne assignment a part interest
Continuation of application Ser. No. 622,183, Mar. 10, 1967, now abandoned.

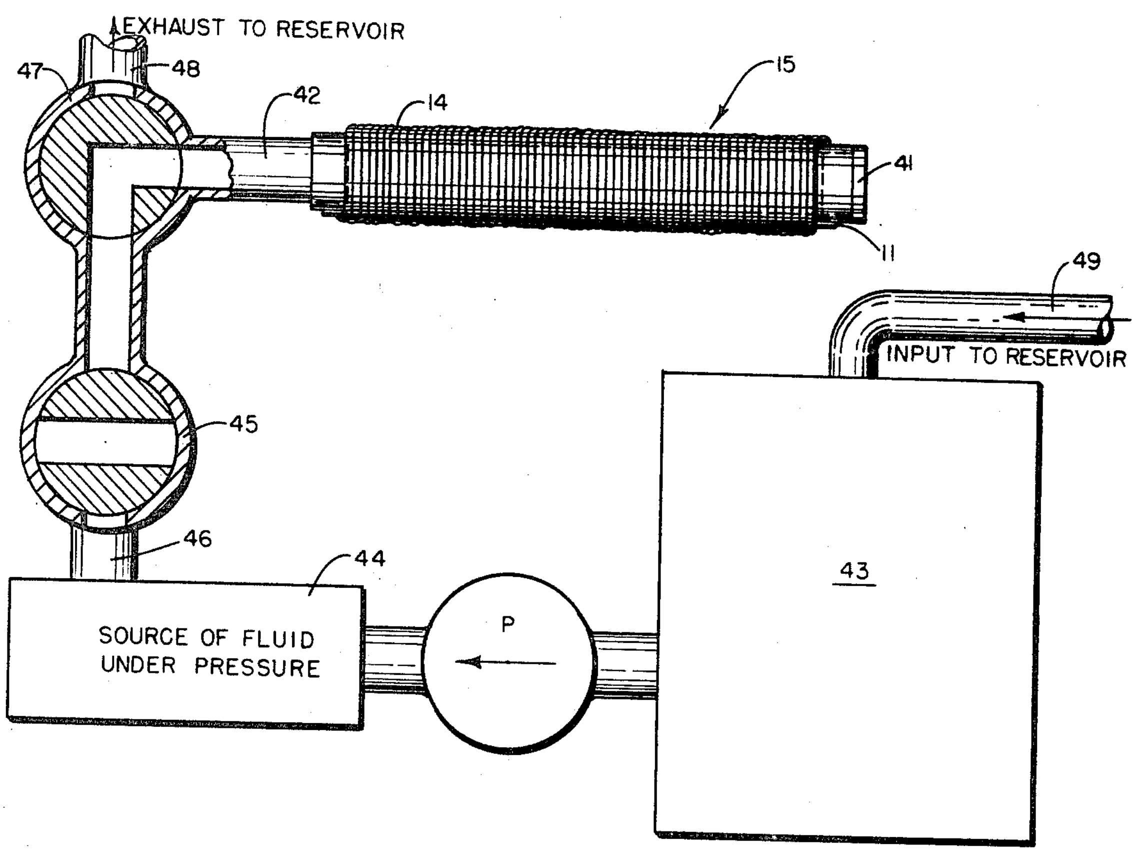
[54] **FLUID OPERABLE MOTOR**
7 Claims, 27 Drawing Figs.

[52] U.S. Cl. 92/92, 73/388, 73/410
[51] Int. Cl. F01b 19/04
[50] Field of Search 73/418, 410, 409, 388; 92/91, 92; 3/1.2, 12.7

[56] **References Cited**
UNITED STATES PATENTS
3,343,864 9/1967 Baer 294/99

Primary Examiner—Donald O. Woodiel
Attorney—Alfred H. Rosen

ABSTRACT: A fluid operable motor element made of a tube of elastic deformable material (e.g. rubber) closed at one end. The tube is restrained against deformation transverse to its longitudinal axis, and against longitudinal deformation in a limited region of its side walls. The remainder of the sidewalls is free to execute elastic deformation in the longitudinal direction. When fluid pressure in the tube is changed to a pressure different from the ambient pressure, the tube flexes about the longitudinally-restrained region of its sidewalls. Methods of making the motor element, several forms of it, and combinations of such motor elements with other devices and with other motor elements to form a pressure gauge, a clamping device, pliers, wrenches, a self-wrapping hook, and an artificial human hand, are described.



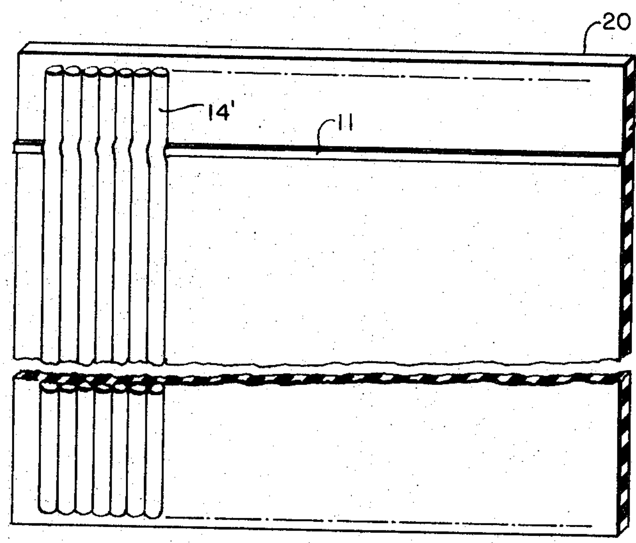


FIG. 2A

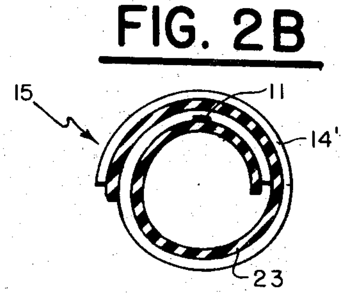


FIG. 2B

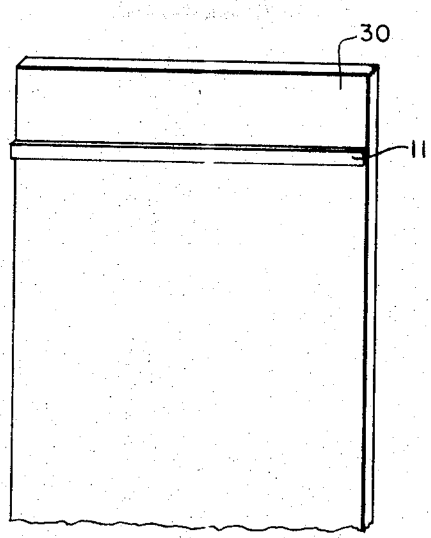


FIG. 3A

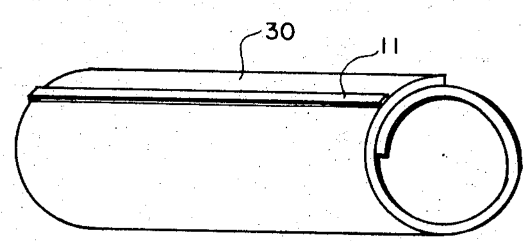


FIG. 3B

Stanley R. Rich
Inventor
by Alfred H. Rosen
Attorney

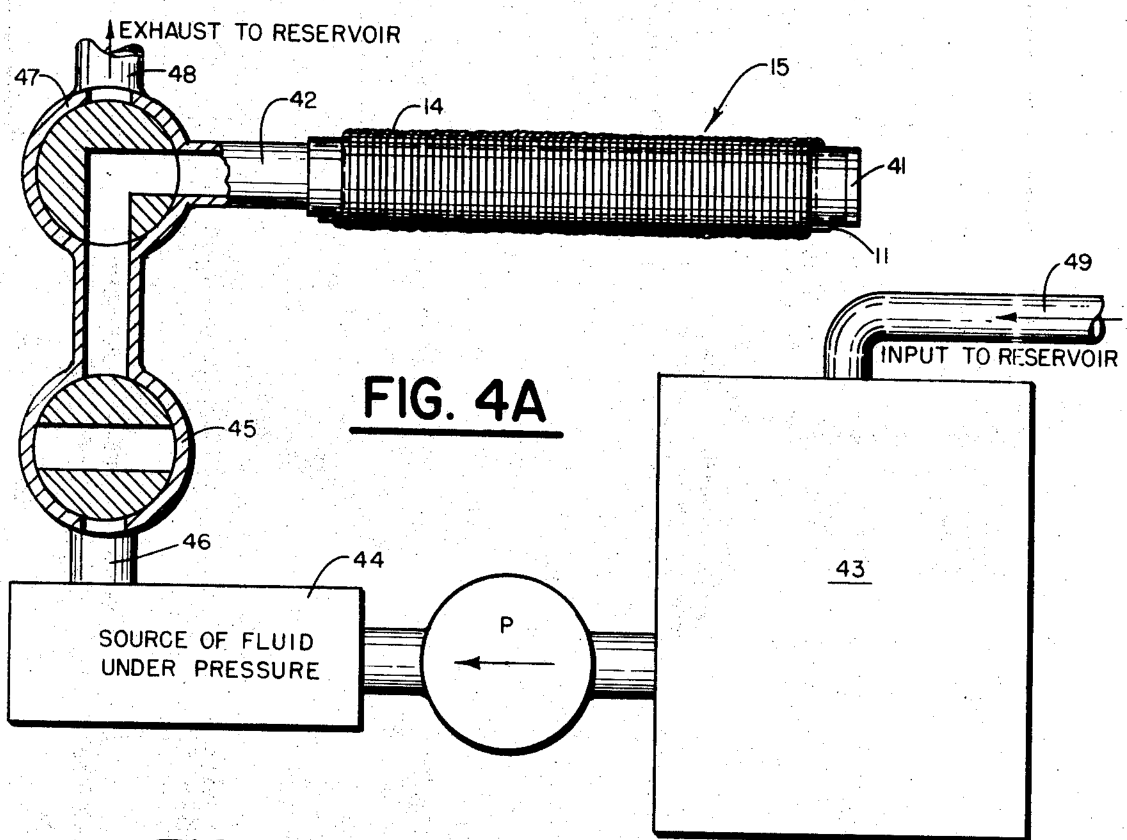
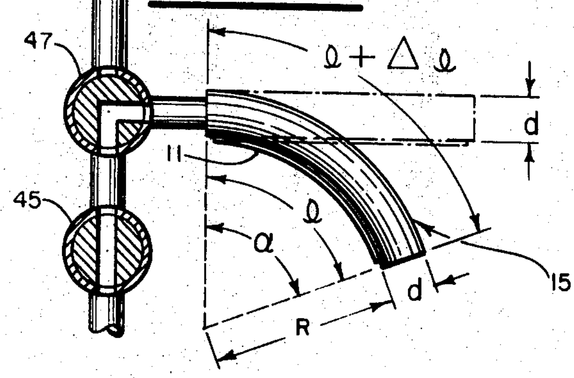


FIG. 4A

FIG. 4B



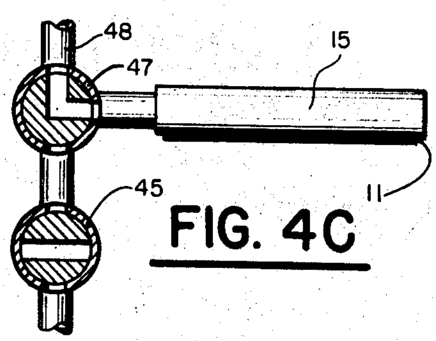
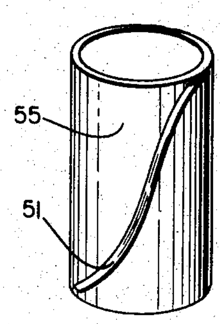


FIG. 4C



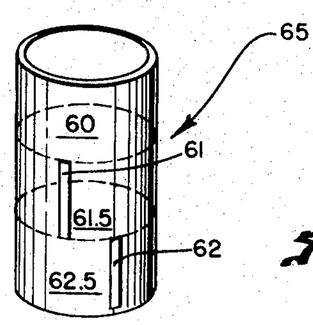


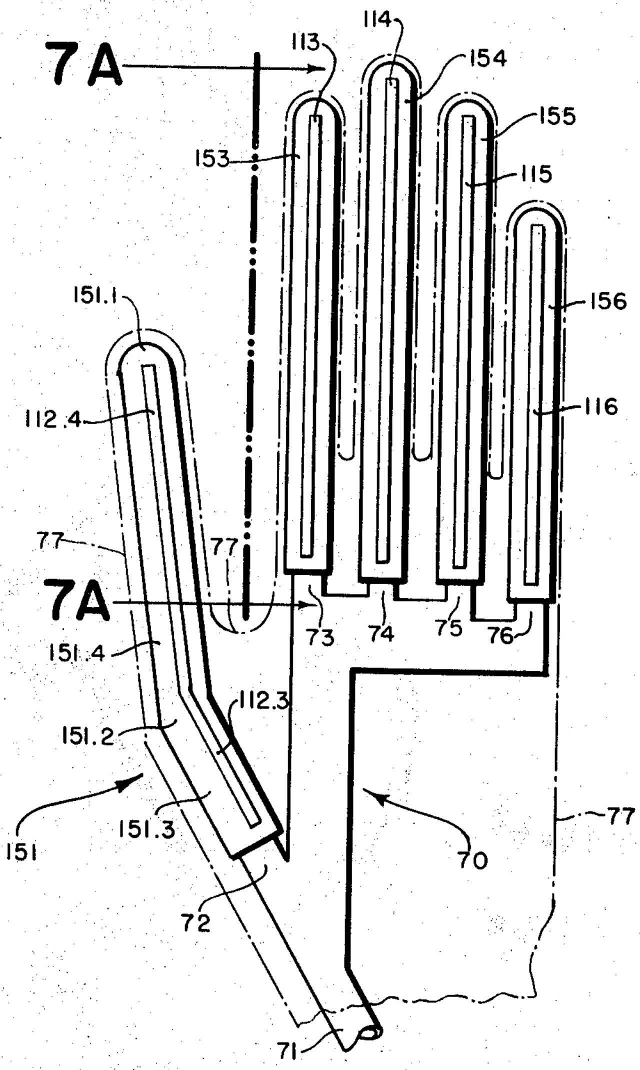
FIG. 5 FIG. 6

Stanley R. Rich
Inventor
by Alfred H. Rosen
Attorney

PATENTED FEB 9 1971

3,561,330

FIG. 7



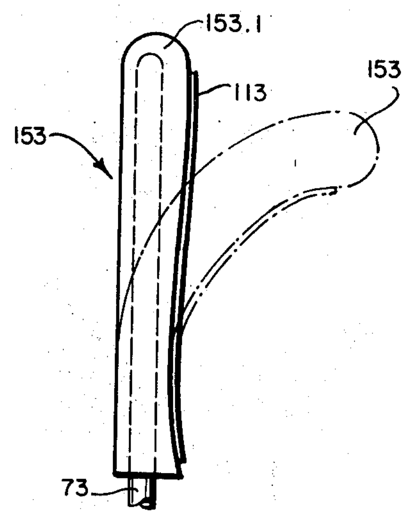


FIG. 7A

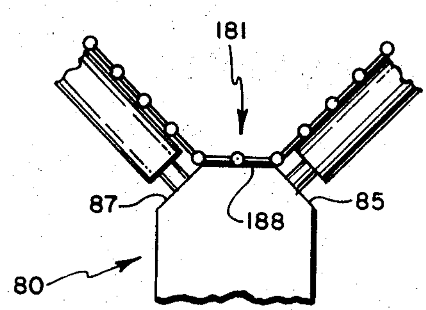


FIG. 13

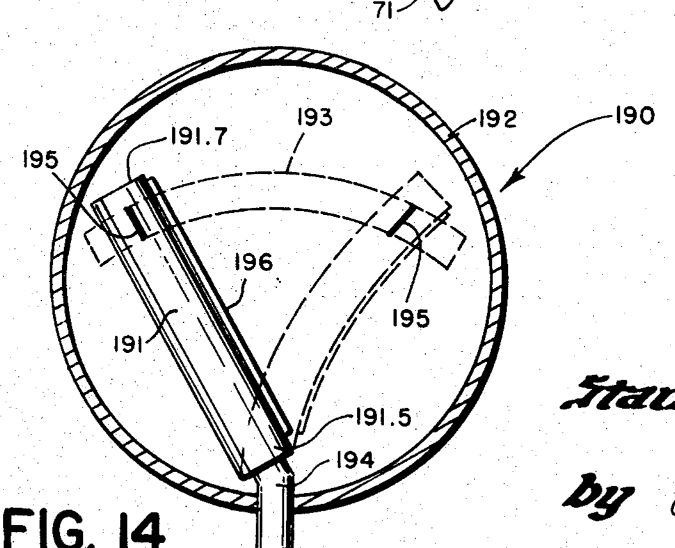


FIG. 14

Stanley R. Rich
Inventor
by Alfred H. Rosen
Attorney

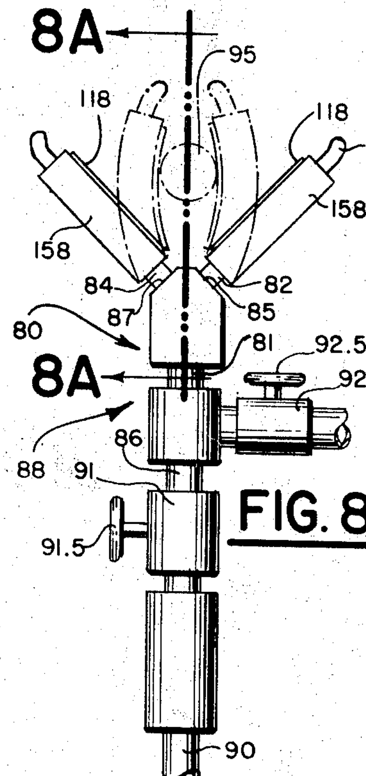


FIG. 8

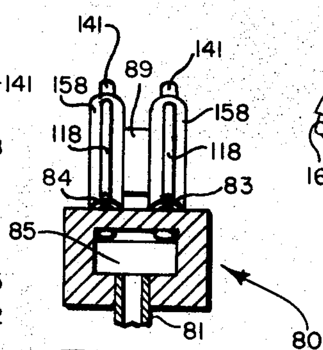


FIG. 8A

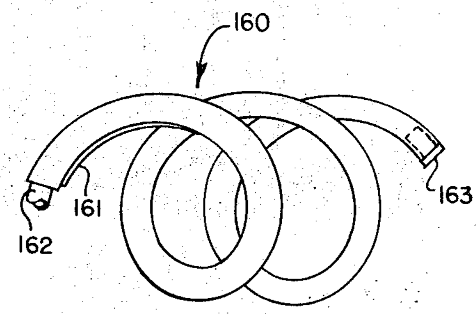


FIG. 9

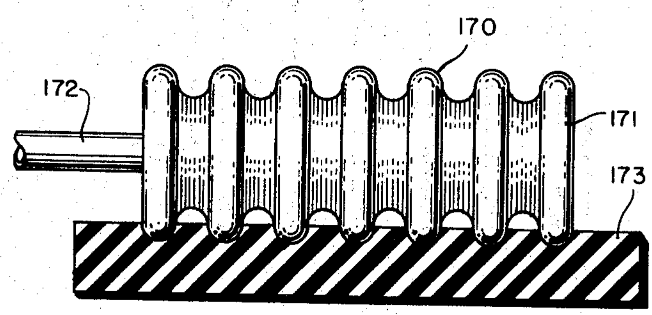


FIG. 10

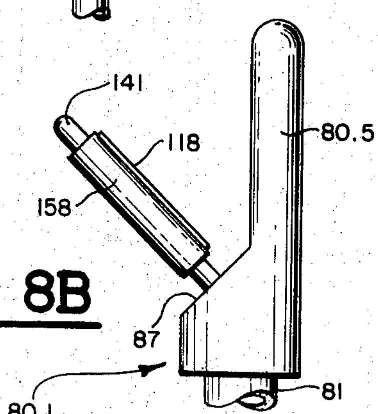
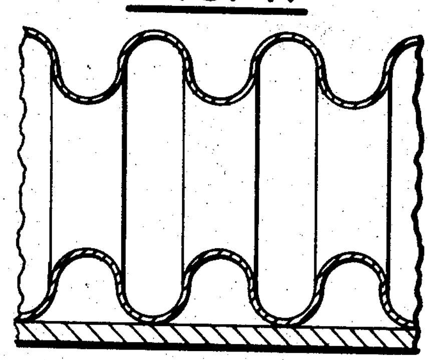


FIG. 8B

FIG. 11



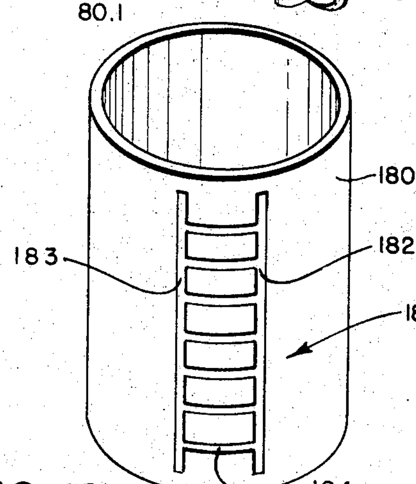


FIG. 12

Stanley R. Rich
Inventor
by Alfred H. Rosen
Attorney

FLUID OPERABLE MOTOR

This application is a streamlined continuation of the copending application Ser. No. 622,183, **filed Mar.** 10, 1967, now abandoned.

BACKGROUND OF THE INVENTION

This invention relates in general to a new form of motor element having the property that it flexes and can exert a force in response to an applied fluid force, and to combinations of such motor elements to provide grasping tools and manipulative and prosthetic devices.

Many classes of tools, grasping devices and manipulative and other devices are known which make use of motor or force-exerting elements which pivot or execute a quasiflexural motion to accomplish their purposes. Some devices such as pliers, some wrenches and clamps (both hand operated and powered) use levers; chain wrenches are another type of device which may be said to encircle the workpiece. Manipulative devices range from small part clamping and assembling devices to remote handling components and systems for radioactive and corrosive materials, and materials at high temperatures. Prosthetic devices, some including manipulative components, frankly seek to duplicate the flexural mode of operation of fingers and other jointed members of the body. To my knowledge, except for rather simple devices of limited application, as in a Bourdon pressure gauge, only levers and links, and combinations of the same, together with cables, pulleys and supporting members supplied with pivots, have heretofore been available for these purposes. Such structures and combinations of them become unwieldy, complex and costly in all but the simplest applications and when the source of applied force is remote from the location at which the result of that force is sought to be used. The present invention is addressed to an entirely new approach which removes the need for levers, links, pivots, pulleys, cables and the like in the foregoing and similar applications.

DESCRIPTION OF THE INVENTION

It is a principal object of the invention to provide a fluid-operable motor element capable of executing a flexural motion in response to an applied fluid force, and methods of making such motor elements. Another important object is to provide such a motor element which can exert force while executing flexural motion, and thereby be used to do work, and to manipulate heavy objects.

A further object of the invention is to provide combinations of such motor elements with other elements, including but not limited to other similar motor elements, for the purpose of making tools such as pliers and wrenches, clamping devices, grasping devices, both hand and power operated, manipulative devices, prosthetic devices, self-actuating hooks, and wrapping devices, as examples.

A more specific object of the invention is to provide an artificial human hand which closely duplicates a human hand in both function and appearance, and which is simple in construction yet capable of executing complex movements.

Another specific object of the invention is to provide pliers, wrenches, clamping and manipulative devices and the like which can conform themselves to the contour of an article being handled.

According to the general object of the invention there is provided a fluid-operable motor element comprising a hollow member of substantially tubular form having sidewalls surrounding a chamber extending on an axis located between said sidewalls, restraining means connected to a portion of said sidewalls for substantially preventing a change in dimension of said portion parallel to said axis, at least a portion of the remainder of said sidewalls in the same transverse region of said member as said restraining means being capable of and free to execute elastic deformation parallel to said axis. The restraining means may, for example, be an elongated flexible but longitudinally substantially inextensible member associated with the wall of the hollow member and extending in the axial direction. When fluid under pressure is admitted to and confined in the chamber of such a motor element, the motor element executes a flexural motion about the restraining means due to elastic deformation parallel to the tube axis of the sidewalls of the hollow member remote from the restraining means. When the fluid is released from the chamber, the motor element returns to its relaxed posture. Only the strength of the materials used, and the pressure applied to the operating fluid, limit the force that can be applied by the motor element, or the work that can be done by it.

I have found, moreover, that when the fluid pressure in the chamber is reduced below the ambient (e.g: atmospheric) pressure, the motor element executed a flexural motion opposite in direction to that executed when the fluid pressure in the chamber is increased above the ambient pressure. Thus, it will be convenient in the specification and the claims to refer to "absolute pressure."

Since the construction, materials, modes of use, methods of manufacture, and applications of new motor elements of the invention, singly or in combination with other similar motor elements, or with other devices or different motor elements, will be limited only by the imagination of the reader, it would be futile to attempt to mention all that are possible. The following description of certain embodiments of the invention, and of several methods to make it, and to apply it singly and in combinations, will suggest more, and will disclose additional objects and features of the invention. Obviously, it is intended that this description shall be taken as illustrative of the invention, and not in a limiting sense, and that, having regard to the fact that the invention opens new areas of development in the art or arts to which it relates, the claims that follow the description are to be given the broadest possible interpretation of which they are susceptible under the law.

This description refers to the accompanying drawings, in which:

FIG. **1** (A—D) shows a method of making a motor element according to the invention;

FIG. **2** (A,B) shows another method of making the motor element;

FIG. **3** (A,B) shows another method of making the motor element;

FIG. **4** (A—C) illustrates a mode of operation of motor elements according to the invention;

FIG. **5** illustrates another embodiment of the invention;

FIG. **6** illustrates still another embodiment of the invention;

FIG. **7** and **7A** illustrate a prosthetic device according to the invention;

FIGS. **8** and **8A** illustrate a manipulative device according to the invention;

FIG. **8B** illustrates a modification of the device of FIG. **8**;

FIG. **9** illustrates another manipulative device according to the invention;

FIG. **10** shows another embodiment of the motor element according to the invention;

FIG. **11** shows an alternative structure according to the concept of FIG. **10**;

FIG. **12** shows a modification applicable in general to motor elements of the invention;

FIG. **13** illustrates a modification of the device of FIG. **8** according to FIG. **12**; and

FIG. **14** illustrates a pressure gauge incorporating a motor element according to the invention as the sole movable element thereof.

FIG. **1** illustrates a method of making a motor element **15** according to the invention. Starting with a tube **10** of hand wrapped india or gum rubber, shown in side view in FIG. **1A**, a longitudinal restraint member **11**, such as a piece of nylon or cotton cord, is attached to the tube along its outer side, running in the axial direction. The restraint member has the property that it is flexible but, compared to the tube **10**, substantially nonextensible; it is attached by a rubber cement, or other suitable adhesive to the tube **10**. A rubber cement available as "Pliobond" (Trademark) from the Goodyear

Rubber Co., is suitable. Next as shown in FIG. 1B, a split mandrel **12, 13** is fitted into the tube **10** and the parts pushed together to fit it snugly in the tube. Then a cord **14**, such as nylon or cotton cord, is helically wrapped tightly around the tube **10** and longitudinal restraint member **11**, as shown schematically in FIG. 1C, until the tube **10** is substantially entirely wrapped helically. This helical winding **14** may then also be bonded to the tube **10**, like the restraint member **11**. As shown in FIG. 1D, the mandrel **12, 13** is removed by pulling its parts away from each other. This is facilitated by lubricating the mandrel parts **12** and **13** with talcum powder, for example, before they are put in the tube (FIG. 1B).

The resulting motor element **15** is capable of longitudinal elongation except where restrained by the longitudinal restraint member **11**. The helically-wrapped cord **14** provides restraint against radial expansion of the tube **10**, while permitting its longitudinal expansion. It is therefore obvious that the motor element of the invention is distinguished from the Bourdon tube and similar devices in both form and function. As is well known a Bourdon tube is flattened in cross section in the relaxed state, and tends to distend or deform transverse to its longitudinal axis when under pressure, thereby producing a straightening effect. There is no differential elastic deformation of its walls parallel to its longitudinal axis. In the present invention, moreover, radial distortion is restrained, and does not enter into the motor function.

A motor element **15** may also be made as shown in FIG. 2, where FIG. 2A shows a rectangular sheet **20** of india or gum rubber, to one side of which the longitudinal restraint member **11** has been attached as by rubber cement. Crossing the rubber sheet, on the same side, and passing over the longitudinal restraint member, are a plurality of pieces of cord **14**: closely placed and fastened as by rubber cement or other suitable adhesive to the rubber sheet **20**. One edge **23** of the sheet, parallel to the transverse cord pieces **14'**, is shown crosshatched, so that it can be found in FIG. 2B. After being so prepared, the sheet **20** is wrapped into a tube, as shown in FIG. 2B, with the transverse cord pieces **14'** on the outside and the longitudinal restraint member **11** embedded in the wall of the tube and extending essentially parallel to the axis of the tube. This procedure provides a motor element similar to that made according to FIG. 1, and may lend itself more easily to mass production. It will be seen that pieces of sheet rubber **20** with cord pieces **11** and **14'** attached can be cut from larger sheets to which longer cords have been previously attached in an appropriate array, and then wrapped into tubes as in FIG. 2B.

FIG. 3 shows another method of producing a motor element **15**, which uses part of the process of FIG. 2 and part of the process of FIG. 1. A sheet **30** of suitable rubber is fitted with the longitudinal restraint member **11**, as shown in FIG. 3A, and then rolled into a tube as shown in FIG. 3B, with the longitudinal restraint member in the desired place, which may be embedded in the wall of the tube, and extending in the axial direction. These steps provide the part shown in FIG. 1A, which is then processed as described above in connection with FIGS. 1B—D, inclusive. It will be understood that further layers or plies of rubber and/or restraint elements may be added, if desired, to motor elements produced by the foregoing methods.

The fundamental mode of operation of a motor element **15** is illustrated in FIG. 4. One end of the tube is stopped with a plug **41**. The other end is fitted over an input pipe **42**. Control mechanism, shown in reduced scale compared to the motor element **15**, comprises a reservoir **43** for a liquid, a pump P for providing a source of fluid under pressure, represented by a box **44** to which the pump is connected via a one-way valve, a stopcock **45** in a riser **46** from the source **44**, and a two-way (three-port) valve **47** connected between the stopcock and the input pipe **42**. A pipe **48** connects from the two-way valve to the reservoir input **49**, to carry exhaust fluid back to the reservoir. A suitable fluid for operating the motor element **15** is water, oil, or other liquid. A compressed gas may also be used, but FIG. 4 is drawn to illustrate operation with a liquid under pressure in excess of ambient.

As the valves **45** and **46** are set in FIG. 4A, the fluid under excess pressure is not permitted to enter the motor element **15**, and it remains relaxed, and undistorted, as shown. When however the stopcock **45** is turned to pass fluid under excess pressure from the source **44** through the three-port valve **47** into the motor element **15**, the motor element flexes about the longitudinal restraint member **11**, as shown in FIG. 4B. Assuming the length of the motor element **15** to be l in the relaxed, or unflexed, state, the outer surface of it furthest removed from the longitudinal restraint member **11** stretches, or elongates, a distance $= \Delta l$, and assumes the length $l + \Delta l$. Under the condition that the motor element **15** has elastic properties that are uniform along its length l, when it is made by fluid pressure to flex from a straight to a curved posture, as shown in FIG. 4B, the longitudinal restraint member **11** describes the arc of a circle, so that $l = R\alpha$ where R is the radius of the circle; and α is the angle of the arc.

Similarly:

$l+\Delta l=\alpha(R+d)$ where d is the diameter of the motor element **15**.

Where $\alpha = 1$ radian:

$l+\Delta l=R+d$

$l=R$

and $\Delta l=d$.

This relationship enables the computation of the amount of fluid that must be added to a given motor element that is full but undeflected in order to achieve a known deflection that will provide an angle $\alpha = 1$ radian.

In the deflected state under excess pressure the motor element is restrained from radial expansion by the circumferentially-wrapped cords **14, 14'**. The tubular structure can change its longitudinal dimension, parallel to its axis, everywhere except where restrained by the longitudinal restraint member **11**. When the fluid under excess pressure is released from the motor element it returns to its relaxed state, due to the elasticity of the underlying tubular member (**10** in FIG. 1, for example), as is shown in FIG. 4C. The stopcock **45** is closed, and the three-port valve **47** is turned to pass fluid from the interior of the motor element **15** to the exhaust conduit **48**. Exhaust fluid may be discarded, or returned to the reservoir **43**, as desired.

As is noted pressure," the motor element **15** can flex in the direction opposite to that shown in FIG. 4B if the fluid in it is brought to a pressure below the ambient (e.g.: atmospheric) pressure. Thus, if one thinks of the applied pressure as an "absolute pressure," which can be less than or greater than the ambient pressure, it will be understood that the motor element **15** can be made to flex in the direction shown in FIG. 4B, or in the opposite direction, as desired.

In FIGS. 4B and 4C the motor element **15** is illustrated, for convenience, simply as a tubular structure having a longitudinal restraint member **11** on it, the radial restraint member(s) **14** or **14'** being omitted but understood to be present. Also, for simplicity, a motor element may be illustrated simply as a tubular structure without showing a stopper for one end or a fluid input for the other, since it is easily understood that such parts will be present in practice. This convention serves to illustrate the basic structure of a motor element, and will be followed in illustrating other embodiments of the invention. Thus, in FIG. 5 there is shown a motor element **55** in tubular form having a restraint member **51** attached to the outer surface of its wall, which extends from one end to the other of the tubular member but in a direction having components both longitudinal and circumferential. When caused to flex, this motor element will tend to take the form of a helix, illustrated in FIG. 9, and if it is long enough will assume the shape of a prehensile tail.

FIG. 6 illustrates the basic structure of another motor element **65**, made of a tubular member **60** having short sections of longitudinal-restraint members **61, 62**, etc. on its outer wall, displaced circumferentially one from another. A motor element made this way will, when caused to flex, execute a compound motion, one transverse region 62.5 flexing about its restraint member 62, while the adjacent transverse region 61.5 flexes in a different direction about its restraint member 61.

Motor elements of the invention can be made in any desired shape in the relaxed condition, and can be made to assume another desired shape in the energized condition. Thus, while the embodiments illustrated generally show motor elements which are straight when relaxed and flexed into a curved shape when energized, it will be understood that a motor element can be curved in the relaxed state and straight in the energized state, or can be curved in the relaxed state and further curved in the energized state. In any case, it is characteristic of motor elements of the invention to flex with an attendant change of shape when energized.

Motor elements of the invention can be combined to cooperated for various manipulative purposes. FIG. 7 shows such a combination to provide an artificial human hand, which can be used as a prosthetic device. A manifold **70** has an input port **71** for operating fluid, and five output ports **72** for a thumb and **73, 74, 75** and **76** for index, middle, ring and little fingers, respectively. Attached to the thumb port **72** is a thumb motor element **152** which has its remote end or tip **152.1** closed and in the general shape of a finger tip. This motor element is bent in the relaxed state at a joint region **152.2** corresponding to the large joint in a human thumb.

A first portion **151.3**, nearer to the thumb port **72**, is essentially straight in the relaxed state, and has a restraint member **112.3**. A second portion **151.4** between the joint region and the tip has a second restraint member **112.4**, and is slightly curved in a convex shape to resemble the ball portion of a human thumb. The thumb motor element **152** can be rotated about the thumb port **72** so that when it is energized its motion will closely approximate that of a human thumb.

An index finger motor element **153** is connected to the index finger port **73**. As seen in FIG. 7A, this motor element can be made with a thicker wall near the root on the palm side of the hand than at the tip or back side, so that when energized its flexure about the restraint member **113** will be nonuniform in a desired pattern. The tip **153.1** is closed and rounded to resemble a finger tip. The remaining fingers **154, 155** and **156** have similarly disposed and oriented restraint members **114, 115** and **116**, respectively, so that when energized all the fingers will flex together, as in a human hand.

The entire structure of FIG. 7 can be enclosed in a suitable sheath **77**, indicated partially enclosing the structure by a dashed line in FIG. 7, to make it look like a human hand. It will be understood that in practice means to affix the artificial hand to an arm, and means to bring fluid to the manifold input **71**, and to discharge fluid therefrom, will be provided. When a suitable fluid, under pressure is introduced into the manifold **70** at the input port **71** the fingers **113—116**, inclusive, flex toward the palm and the thumb **152** flexes toward the flexed fingers, as in a human hand. The forefinger **113** is shown partly flexed at **113'**, in FIG. 7A. When the fluid pressure is released, the fingers and thumb relax, and resume the shape shown in FIG. 7.

An artificial human hand has been constructed according to FIG. 7, and has shown itself capable of grasping objects such as cans, bottles and ping-pong balls, and has actually "shaken hands" with a person with an effect remarkably similar to a true human hand.

FIGS. **8** and **8A** illustrate a manipulative tool which can be used as a grasping device, or a wrench. A manifold member **80** has an input port **81** and four output ports, of which only three ports **82, 83** and **84** are shown, connected together by an interior plenum chamber **85**. Operating fluid (not shown) under suitable pressure is brought to the input port **81** over a conduit **90** through a normally closed control valve **91**, pipe section **86** and tee **88**. A normally closed pressure-relief valve **92** is fitted to the tee **88**. Each valve **91** or **92** is of a type which can be momentarily opened by pressing a button **91.5** or **92.5**, respectively, fitted to it, and which resumes its normally closed state when the button is released. Thus, when the control valve button **91.5** is depressed, fluid under pressure may be admitted to the plenum chamber **85**, and when the pressure-relief valve button **92.5** is depressed fluid under pressure may be released from the plenum chamber.

A motor element **158** with restraint member **118** is fitted to each output port. As seen in FIG. **8A**, there are two output ports on each sloped side **85, 87** of the manifold. The FIG. shows one pair of adjoining motor elements fitted to the output ports **83, 84** on one sloped side **85**, connected together by a web **89**. Referring to FIG. **8**, when fluid under pressure is admitted to the plenum chamber **85** the motor elements flex toward each other from the sloped sides **85** and **87**. If an object, such as a can or bottle **95** (shown in dotted line) is being grasped, the use of pairs of motor elements joined to each other as by a web **89** assures a firm grasping of the object. I have found that if a single motor element **158** is used on each side of the grasping device, there is a risk of scissorslike motion, as when one attempts to grasp a device between only two fingers, which may result in dropping the article being grasped.

The ends of the motor elements **158** are closed with fingerlike projections **141**, which are useful in picking up small objects. Either or both of the projections **141** and the confronting surfaces of the motor elements along the restraint regions may be made rough, to enhance the ability of the device to hold objects, and to function as a wrench.

The tool of FIG. **8** can be modified as shown in FIG. **8B**, to substitute a platform member **80.5** on one side of the manifold member **80.1**, which in other respects is the same as the manifold member **80**. The motor element or elements **158** on the sloped side **87** which remains will then act to flex toward and away from the platform member **80.5** when the tool is in use.

FIG. **9** shows a greatly elongated motor element **160** having restraint **161** along its side, an input conduit **162** at one end and a closure **163** at the other end. The constraint may be configured according to FIG. **5**. A motor element in this configuration will wrap itself around an object in helical fashion when fluid under pressure is supplied to it. It may be used as a grasping device for objects of various shapes. If attached at the end of a lifting device, such as a chain fall or a cable, it can function as a self-attaching hook.

The fundamental mode of operation of the invention can be realized in structures different from that shown in FIGS. **1** to **3**. Thus, in FIG. **10**, a bellows **170**, which can be made of metal, closed at one end **171** and having an input conduit **172** at the other, is constrained at one side by a flexible but substantially longitudinally inextensible member **173**. Alternatively in FIG. **11** a tubular member **175** having convoluted walls may be used, with constraint **176** along one side of the walls; in this case the walls may be made of a material which is longitudinally extensible, like the circumferentially restrained motor element **15**, the convoluted form of the walls contributing additional longitudinal freedom.

A motor element which resists the tendency to assume a helical configuration when flexed due to applied fluid under pressure is shown in FIG. **12**. Here a tubular member **180**, similar in all respects to the circumferentially restrained tubular member of the motor element **15** (FIGS. **1—3**) is supplied with a longitudinal restraint member **181** in the form of two side elements **182** and **183** joined by cross-elements **184**. This restraint member is preferably made in the manner of a bicycle chain, so that it resists twisting, and a motor element using it will then tend to flex in a plane. Such motor elements may be used singly on either side **85, 87** of the manipulative tool shown in FIG. **8**, as is illustrated in FIG. **13**. In this case, the restraint member **181**, if in the form of a bicycle chain, can be a single restraint member extending between both motor elements, and can be joined at an intermediate region to the top wall **188** of the manifold **80**. This arrangement provides a highly improved chain wrench.

FIG. 14 shows a pressure gauge **190** incorporating a motor element **191** according to the invention. The gauge has a housing **192** provided with a cover (not shown) having an arcuate window **193** shown in dashed outline. The motor element is mounted at the pressure input end **191.5** in a tube **194** passing through the housing **192** and bent inside the housing so that when the motor element **191** is in the relaxed state its closed end **191.7** lies under the left hand end (in FIG. **14**) of the window **193**. An indicator mark **195** is on the motor element near the closed end **191.7** and disposed to be visible through the window **193**. The longitudinal restraint member **196** of the motor element **191** is so oriented that when fluid under pressure in excess of ambient atmospheric pressure is admitted to the motor element (via the tube **194**) the motor element flexes to the right (in FIG. **14**) and the indicator mark **195** moves along the window **193**. Indicia (not shown) can be located along the window so that deflection of the indicator mark **195** can indicate the pressure applied at the tube **194**. This arrangement is a sensitive pressure gauge, which can be made to measure small pressure changes over a full scale deflection of the indicator mark **195**. Unlike Bourdon gauges, which flex only very slightly, the gauge of FIG. **14** does not require additional mechanical elements to move a pointer over a scale. The motor element **191** is the sole movable member. It will be understood that the gauge **190** can be designed to measure absolute pressures as well as relative pressures, since as is explained above, the motor element **191** can flex in response to applied pressure below ambient in addition to applied pressure in excess of ambient.

I claim:

1. An elongated tubular body comprising a structure which is limited against circumferential extension substantially uniformly throughout its length, a longitudinal section of said structure being limited against extension in the longitudinal direction, the remainder of said structure being reversibly extensible in said longitudinal direction, whereby inflation of said structure with a fluid will cause said structure to flex.

2. An elongated tubular body comprising a flexible structure, means for limiting said structure against circumferential extension substantially uniformly throughout its length, means for limiting a longitudinal section of said structure against extension in the longitudinal direction, the remainder of said structure being reversibly extensible in the longitudinal direction, whereby inflation of said structure with a fluid will cause said structure to flex.

3. A tubular body according to claim **2** in which said means for limiting against circumferential extension comprises elongated substantially nonextensible material oriented transversely to said longitudinal direction in restraining relation with the walls of said body.

4. A tubular body according to claim **3** in which said limiting means is a continuous helix of said elongated material.

5. A tubular body according to claim **2** in which said means for limiting said longitudinal section against extension comprises flexible but substantially nonextensible material oriented in said longitudinal direction in restraining relation with said longitudinal section.

6. A tubular body according to claim **2** in which said structure is a tube of flexible elastic material, and said limiting means are cordlike members of substantial nonextensible material.

7. A tubular body according to claim **1**, a wall of which varies in thickness along said longitudinal direction, whereby inflation of said structure with a fluid will cause said structure to flex nonuniformly along said direction.

Notice of Adverse Decision in Interference

In Interference No. 97,955 involving Patent No. 3,561,330, S. R. Rich, FLUID OPERABLE MOTOR, final judgment adverse to the patentee was rendered Oct. 11, 1973, as to claims 1, 2, 3, 5 and 6.

[*Official Gazette February 26, 1974.*]