March 23, 1971 S. BAZELL ET AL 3,572,325

FLEXIBLE ENDOSCOPE HAVING FLUID CONDUITS AND CONTROL

Filed Oct. 25, 1968 2 Sheets-Sheet 1

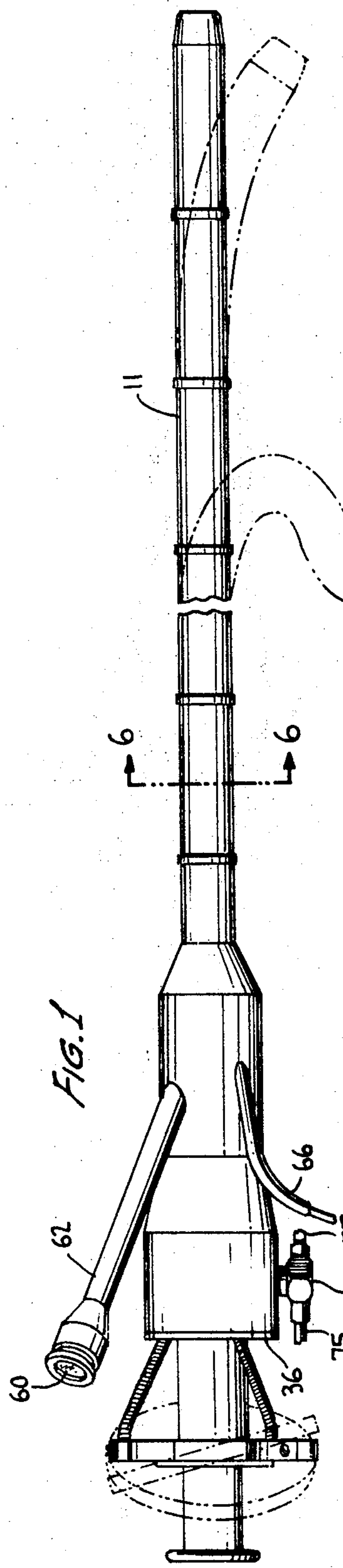

FIG. 1

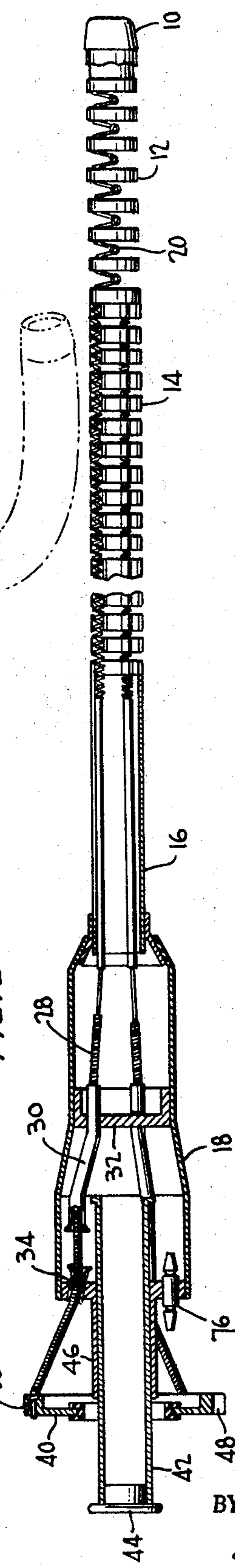

FIG. 2

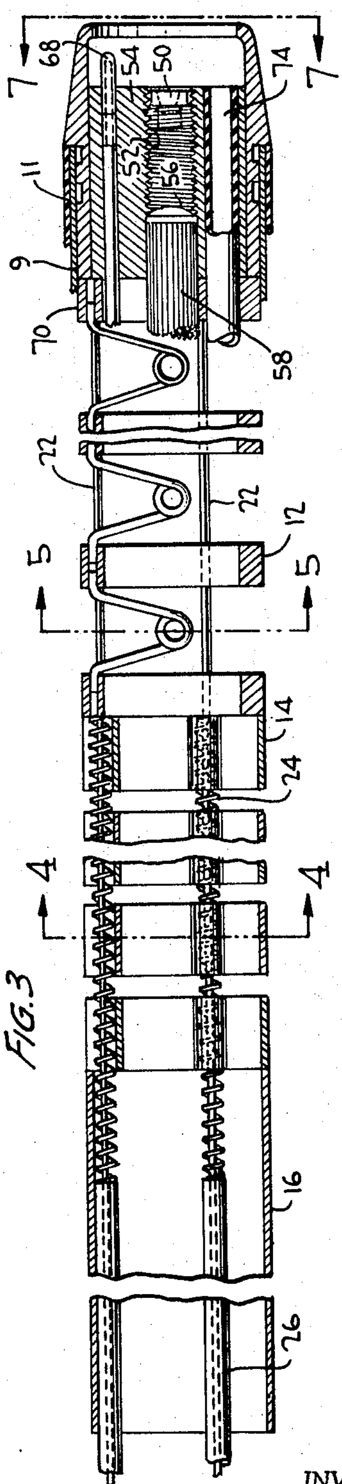

FIG. 3

INVENTORS,
WILLIAM E. REYNOLDS
SEYMOUR BAZELL
ANATOLI BRUSHENKO
DONALD A. PONTARELLI
BERGEIN F. OVERHOLT

BY Jacobi & Davidson
ATTORNEYS

FLEXIBLE ENDOSCOPE HAVING FLUID CONDUITS AND CONTROL

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FIG. 4

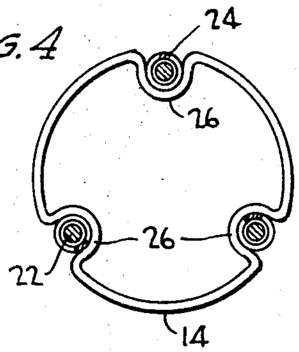


FIG. 5

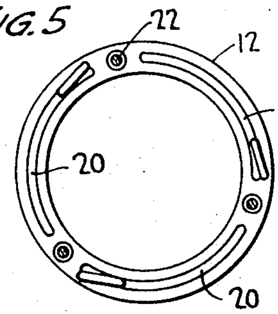


FIG. 6

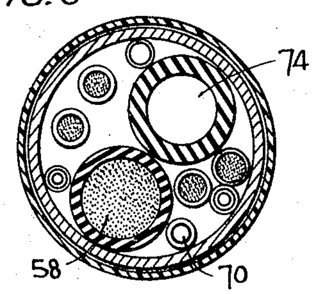
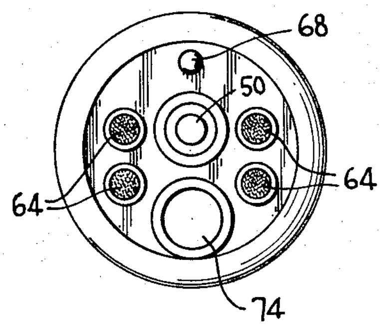


FIG. 7



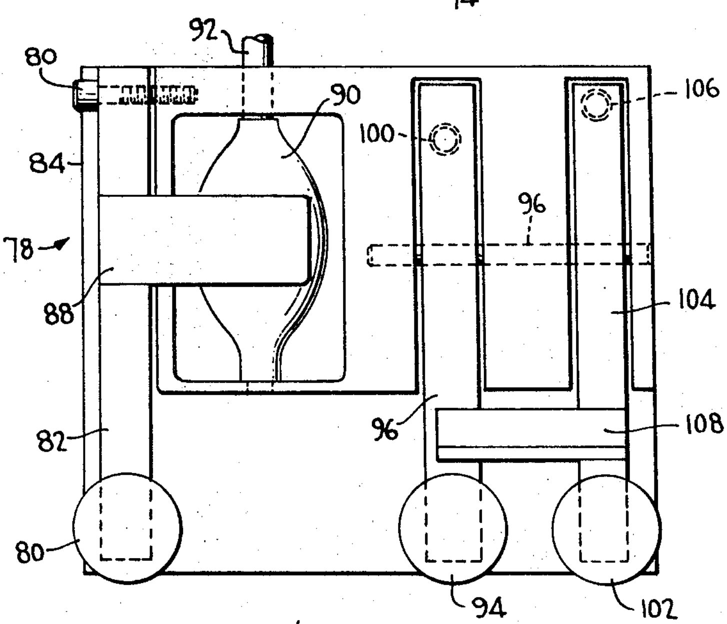


FIG. 8

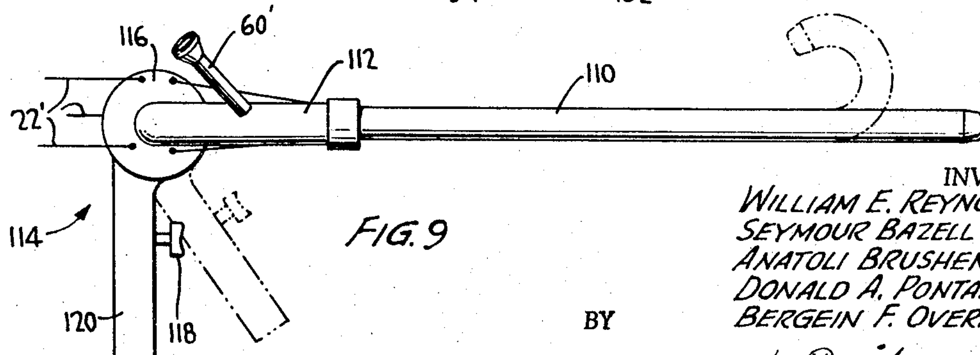


FIG. 9

INVENTORS,
WILLIAM E. REYNOLDS
SEYMOUR BAZELL
ANATOLI BRUSHENKO
DONALD A. PONTARELLI
BERGEIN F. OVERHOLT

BY Jacobi & Davidson
ATTORNEYS

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FLEXIBLE ENDOSCOPE HAVING FLUID CONDUITS AND CONTROL

Seymour Bazell, Chicago, Ill., William E. Reynolds, Western Springs, N.J., Anatoli Brushenko, Elmhurst, and Donald A. Pontarelli, Chicago, Ill., and Bergein F. Overholt, New York, N.Y., assignors to the United States of America as represented by the Secretary of Health, Education, and Welfare

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U.S. Cl. 128—6 13 Claims

ABSTRACT OF THE DISCLOSURE

An endoscope having a flexible distal end portion comprising a distal tip and plurality of articulated segments, a less flexible central portion, a rigid proximal end, a control assembly operated at the proximal end and including control wires passing through the apparatus to the distal tip, and a fiber bundle optical system. A conduit for supplying water and air and an aspiration conduit may also be provided within the endoscope.

The present invention relates to an endoscope and more particularly to a flexible endoscope which is particularly adapted for use as a sigmoidoscope, that is, for examination of the sigmoid region of the colon.

The sigmoidoscope was first developed approximately 75 years ago, and is today an accepted instrument in general physical examinations. Although flexible sigmoidoscopes have been proposed heretofore, the type of sigmoidoscope which is commonly used at present is a rigid instrument which has proved inadequate in reaching the lower intenstine which is subject to a large portion of colonic diseases. In addition, a high percentage of patients cannot tolerate the full length of the instrument which is about 25 cm. The problems associated with such a prior art instrument are evident from the configuration of the colon or lower intentine. The sigmoid region is reached only after two curves of the intestine, which curves together, form an essentially reverse S shaped channel, have been navigated.

In view of the natural configuration of the intestinal tract, a suitable sigmoidoscope should be flexible and readily manipulatable. Such an instrument should also have an effective length which will enable it to explore from 50 to 60 centimeters of the lower intestinal tract, have proximally controlled maneuverability of the distal end to a radius of about 1½ inches without change in proximal configuration, have a distal end optical system including a fixed focus lens of visual clarity from 12 mm. to 10 cm. with a field of view of 50°, and should be capable of chemical sterilization. In addition, the instrument should include a conduit for the injection of air and water at the distal end thereby facilitating cleaning of the lens as well as allowing insufflation, and an aspiration conduit which, when decoupled at the proximal end, may also serve as a biopsy channel.

A principal object of the present invention is to provide an improved flexible endoscope which has increased flexibility and maneuverability of its distal end via readily manipulatable control means at the proximal end. Another object of the present invention is to provide a flexible endoscope which complies with the aforementioned specifications for successful use as a sigmoidoscope.

The endoscope of the present invention includes a readily flexible distal end section comprised of a rigid distal tip and a first plurality of articulated annular segments which are connected to each other by small hairpin type springs, a central section of less flexibility comprised

of a second plurality of articulated annular segments, and a rigid annular proximal end section. The springs in the distal end are of smaller diameter adjacent the distal tip where it is desired to have a shorter radius of curvature. With this arrangement, the front group of springs will compress before the remaining springs which interconnect segments of the distal end portion. Glass or plastic fiber bundles are passed through the center of the endoscope for the transfer of an image from the distal end to the proximal end. Control wires attached to the distal end also pass through the endoscope and at the proximal end are attached to manually operable control means which may be a wobble plate. Alternatively, the control means may include a pistol grip handle arrangement. Control of the injection of air or water and control of the aspiration conduit are preferably carried out by a foot actuated lever system.

The above and other objects, features and advantages of the invention will become more apparent from the following detailed description when considered in conjunction with the drawings in which:

FIG. 1 is an elevational view of one embodiment of the invention.

FIG. 2 is in part a side view and in part a vertical cross sectional view of the endoscope of FIG. 1 with some parts of the apparatus omitted for the sake of clarity.

FIG. 3 is a vertical cross sectional view on an enlarged scale of portions of the embodiment of FIG. 1.

FIG. 4 is a transverse cross sectional view taken on the line 4—4 of FIG. 3.

FIG. 5 is a transverse cross sectional view taken on the line 5—5 of FIG. 3.

FIG. 6 is a transverse cross sectional view taken on the line 6—6 of FIG. 1 illustrating the arrangement of the internal parts of the central portion of the endoscope.

FIG. 7 is an end view of the distal tip as seen from the plane 7—7 of FIG. 3.

FIG. 8 is a plan view of foot actuated control means for the insufflation and aspiration conduits.

FIG. 9 is an elevational view of another embodiment of the invention employing pistol grip control means at the proximal end.

Referring now to FIGS. 1 and 2, the endoscope of the invention includes three main sections, namely, a readily flexible distal end section comprising a rigid distal tip **10** and a plurality of interconnected annular segments **12**, a less flexible central section formed of a plurality of interconnected annular segments **14**, and a proximal end section comprising a rigid stainless steel tube **16**. A housing **18** is connected to the end of the tube **16** to house portions of the optical system and other apparatus as will be described hereinafter. An annealed T–302/304 stainless steel plain weave tubular braid **9** which has been impregnated with silicone rubber encases the distal and central sections of the endoscope. This is, in turn, covered by a flexible vinyl covering **11**. The tubular braid was found necessary to provide torsional stability during manipulation of the distal tip.

At the distal end, the outermost segment **12** is soldered to the distal tip **10** and the innermost segment **12** is soldered to the adjacent segment **14** of the flexible central section. Each annular segment **12** is connected to the adjacent segment or segments **12** by three hairpin type springs **20** which have an arcuate shape corresponding to the curvature of segments **20**, as viewed in a plane transverse to the axis of the endoscope as is best seen in FIG. 5. The ends of springs **20** are soldered to the segments **12**. A front group of sets of springs **20**, for example, the first three sets, are of less strength, e.g. of smaller diameter, than the remainder of the springs. The finer springs have a shorter radius of curvature than the remaining springs. By virtue of this arrangement there is formed, in effect, a spring loaded segmental column, which, when an unbalanced force is applied, will cause the front end group of springs to compress first. As more force is applied, the springs will compress further until subsequently the larger diameter wire springs begin to compress. Thus, upon the application of force during use, the distal end will ultimately assume a rather smooth curvature.

As an illustration of suitable relative sizes of the components, one embodiment of the invention in keeping with the above description has been constructed with a distal end (exclusive of the distal tip **10**) which is approximately 4 inches long. The average distance between the segments **12** was 5/16 inch, the front group of springs **20** had a diameter of 0.015 inch and the remaining springs had a diameter of 0.018 inch.

Three control wires **22**, which are evenly spaced at 120° intervals around the periphery of the endoscope, are soldered to the first segment **12** at their distal ends, and then freely pass through apertures in the remaining segments **12** and through the center of wire coils **24** which serve as guide members. Wire coils **24** are soldered within arcuate recesses **26** in the outer periphery of segments **14** of the central section of the endoscope and serve to space the segments **14** of the central section and provide a limited amount of flexibility. Preferably, the segments **14** adjacent the distal end section are spaced wider apart than the segments **14** adjacent the proximal end section so that the front part of the central section is more flexible than its rear part. By way of illustration, if the central section is approximately 33 centimeters long, the segments forming the front 13 centimeters may be spaced about 3/16 inch apart and the segments of the remaining 20 centimeters of the central section may be spaced about 1/8 inch apart. The wire coils **24** extend a short distance into the tube **16** and their ends are soldered to the ends of guide tubes **26** which in turn are soldered to the inner surface of tube **16**.

The control wires **22** then pass through guide tubes **26** into the housing **18** where they are reinforced by an outer wrapping of twisted cable **28**. The cables **28** are supported by guides **30** mounted on a transverse reinforcing member **32** and by guides **34** which extend through the rear wall **36** of the housing **18**. The proximal ends of control wires **22** are secured by set screws **38** to an annular manually operated wobble control plate **40**. The wobble plate is disposed around a tubular member **42** which is provided at its outer end with a stop **44**. The tubular member **42** is mounted within a tubular suporting flange **46** which is secured to the rear wall **36** of the housing.

The procedure for manipulating the endoscope will now be described. Assuming that it is desired to have the distal end assume a curved configuration, for example, as it enters the first channel of the intestinal tract, and assuming further that the desired direction of curvature is downwardly as seen in FIG. 1; the wobble plate **40**, which has indentations **48** on its outer periphery to serve as finger grip, is grasped by the operator and moved clockwise as seen in FIGS. 1 and 2. This movement of the wobble plate causes tension to be applied to the two lower control wires **22** while a compressive force is applied to the upper control wire. This relative shortening of the lower control wires causes the distal tip **10** and the adjacent portion of the distal end of the endoscope to be pulled downwardly to the dash line position shown in FIG. 1. During this time, the springs **20** between the annular segments **12** of the distal end section have been compressed or expanded as the case may be to accommodate the relative shortening of the lower surface of the distal end section and the relative lengthening of its upper surface. The first set of springs which are of smaller diameter as mentioned above react first. Upon the application of further force via manipulation of the wobble plate **40** and the control wires **22**, the remainder of the springs are compressed or expanded as the case may be to accommodate further curvature of the distal end. It will be appreciated that the greater the amount of movement of the control plate **40** in a given direction, the greater is the amount of curvature obtained, that is, increasing the pull on one or two of the control wires decreases the radius of curvature of the distal end section. The operator, by employing the optical system to be described hereinafter, determines the appropriate amount of curvature, and at the proper time may reverse the curvature to traverse the second channel of the intestinal tract by swinging the wobble plate in the opposite direction.

One of the advantages of the endoscope of the invention is that movement of the wobble plate and hence of one or more of the control wires **22** is effective to cause a corresponding change in the configuration of the front segments **12** of the distal end section without initially changing the configuration of the remainder of the instrument. Since the front segments **12** are interconnected by springs **20** of thin wire as stated above, the front portion of the distal end section changes configuration first followed by the remainder of the distal end section. Assuming that the distal end section has been manipulated into the appropriate configuration to pass through one of the curves of the intestinal tract, upon further insertion of the instrument, the less flexible central section will, in effect, follow in the path of the distal end. The central section, although less flexible than the distal end section, nevertheless has sufficient flexibility to follow the curved path established by the distal end section. Thus, after the distal end has been manipulated through the second channel of the intestinal tract, the distal end and central sections of the instrument may assume the essentially reverse S shaped configuration shown in dash lines in FIG. 1.

The optical system of the invention includes an objective lens **50** mounted in a lens holder **52** which is threadably secured in an aperture in a support block **54** disposed within the distal tip **10**. The face of objective lens **50** is recessed from the end of the distal tip **10** since the mucosa has a tendency to fold in on the lens. If desired, a thin transparent shield, for example, a quartz window may be installed in front of the objective lens to protect it from the etching action of sterilization solution which is used during the sterilization of the instrument. A field lens **56** positioned within support block **54** is cemented to the end of a coherent fiber optic bundle **58**.

By way of example, the objective lens **50** may be a 3 mm. focal length planoconvex F:2 in order to cover the required angular field of view. An advantage of this short focal length lens is a large depth of field even when the lens is focused for an object distance of 6 times the focal length. A 10.4 mm. lens may be used as the field lens **56**.

From the distal tip **10**, the bundle **58** passes rearwardly through the center of the instrument into housing **18**. The image transmitted by the bundle is viewed through an eye piece **60** at the end of a tubular eye piece extension **62** which projects upwardly from the housing **18**.

Illumination is supplied via four fiber optic bundles **64** which terminate at the distal end at the front face of support block **54**. The fiber bundles **64** pass rearwardly through the center of the instrument into a protective sheathing **66** which passes through the side of housing **18** to a suitable source of illumination, (not shown).

The fiber bundles **58** and **64** may be made of glass fibers but are preferably made of synthetic plastic fibers which have improved flexibility but rather low tensile strength. This drawback of plastic fibers may be circumvented by installing load bearing shorter fibers, for example, nylon monofilament or silk thread between the distal and proximal ends so that the stresses are thus on the shorter strands rather than on the individual plastic fibers of the optic bundles.

A nozzle **68** for water or air projects from the face of support block **54**. The nozzle is connected to a tube **70** which extends through the instrument into housing **18** to a valve casing **72** to which air and water are supplied via lines **75** and **77** respectively. Valve casing **72** contains one way ball valves at the ends of lines **75** and **77**. The outlet of nozzle **68** is disposed so that it may be employed to wash the face of lens **50** and the ends of the fiber bundles **64**. Air may be supplied through line **75** and tube **70** for insufflation or distention of the colon.

A flexible tube **74** which has its front end mounted in the face of support block **54** also extends through the instrument to a vacuum source and functions as an aspiration channel. When attached to a fitting **76** (FIG. 2) tube **74** may be employed in obtaining biopsy samples.

FIG. 8 illustrates a foot operated control valve unit **78** which is used to control the supply of air and water, and the application of suction of the instrument. The supply of air is regulated by depressing a foot pedal **80** on a control lever **82**. The other end of control lever **82** is pivotally secured to the frame **84** of the unit by a screw **86**. A cross piece **88** attached to control lever **82**, upon depression of the foot pedal **80**, compresses an air filled bulb **90** and forces air out tube **92** to the instrument.

Vacuum is applied by depressing a foot petal **94** on a control lever **96**. Control lever **96** is pivotally mounted on a transverse shaft **98** which passes through a center portion of lever **96**. A coil spring **100** located adjacent the other end of lever **96** normally biases that end of the lever downwardly so that a break edge type clamping member (not shown) on the under surface of lever **96** normally pinches and closes off a suction tube (not shown). Upon depression of the foot petal **94**, the clamping member is moved upwardly against the action of spring **100** to open the suction tube.

In a similar fashion, water is supplied to the instrument by a foot pedal **102** on a control lever **104** which is pivotally mounted on the shaft **98**. The water supply line is normally clamped shut by a break edge type clamping member on the under surface of control lever **104**. Upon depression of the foot pedal **102**, the clamping member is elevated out of contact with the water supply line against the bias of a spring **106** which normally maintains the clamping member in a closed position. As seen in FIG. 8, a transverse bar **108** has its right end welded or otherwise suitably secured to the top of control lever **104** adjacent foot pedal **102**. The free end of bar **108** overlies the control lever **96** which is associated with suction line. Thus, depression of the foot pedal **102** to its lowermost position also causes depression of control lever **96** so that water cannot be supplied without simultaneously applying suction to subsequently remove the water.

An advantage of the pinch type closing of the water and suction tubes is that these tubes may be continuous through the unit and are simply pinched off by the spring loaded foot levers when not in use. Between examinations, the short sections of the tubes are withdrawn and replaced so that it is unnecessary to sterilize the entire control unit of FIG. 8.

FIG. 9 illustrates another embodiment of the present invention employing a modified control assembly.

The endoscope of this embodiment which is generally indicated by reference numeral **110** is substantially identical to the endoscope of the above described embodiment with the exception that a generally tubular housing **112** is provided in lieu of the housing **18** of the FIG. 1 embodiment and a pistol grip control assembly **114** is provided in lieu of the wobble plate control mechanism of the FIG. 1 embodiment. In this embodiment, the three control wires **22′** project out apertures in the housing **112** and then freely pass through three equally spaced bores provided in a control ball **116**. Squeezing the finger control piece **118** of a pistol handle **120** causes the three control wires **22′** to be locked to the control ball by suitable means, for example, by clamping means (not shown). Then, movement of the handle **120** is effective to manipulate the distal end of the instrument. For example, if the

handle is moved to the piston shown in dash lines in FIG. 9, this causes the upper control wire to be tensioned resulting in the distal end of the endoscope bending upwardly toward the position shown in dash lines at the right hand side of FIG. 9. Unless the finger piece **118** is depressed, the control wires are free to move through the control ball **116** to allow the central section of the instrument to assume configurations other than a straight line. Being able to disengage the control wires from the control ball has the further advantage that, with the control wires disengaged, inadvertent movement of the control ball will not change the configuration of the endoscope. The portions of these control wires which pass through the control ball are preferably wound cable of 1/32 inch diameter and its surface roughness aids in locking the cables to the control ball when the control handle is to be manipulated. By this arrangement, the distal end of the instrument is fully controllable towards any point of a circle normal to the longitudinal axis of the instrument.

This embodiment employs an eye piece **60′** similar to the eye piece **60** of the FIG. 1 embodiment. Also, it will be appreciated that there are provided means (not shown) for connecting the endoscope of this embodiment to a light source and to water, air and suction lines as described above in connection with the FIG. 1 embodiment.

Forty patients were examined using the flexible endoscope of the present invention and also a conventional rigid endoscope. The two instruments were inserted only until significant discomfort was expressed by the patients. The comparative distances inserted are tabulated in the table below.

	Number of tests	
Length inserted (cm.)	Rigid endoscope	Flexible endoscope
15	6	2
15–20	12	5
21–25	19	1
26–30		14
31–35		4
36–40		6
40		5
47		2
50		1

The above data shows that the flexible endoscope of the invention may be inserted for greater distances before patient discomfort becomes significant. Employing the prior art instrument, only 41% of the patients were examined to a distance of 25 centimeters, whereas this distance was reached in 80% of the patients employing the flexible endoscope of the present invention.

While preferred embodiments of the invention have been shown and described, it will be appreciated that various changes and modifications may readily suggest themselves to those of ordinary skill in the art. It is intended to cover all such changes and modifications as fall within the scope and spirit of the appended claims.

What is claimed is:

1. An endoscope comprising a readily flexible distal end section including a distal tip and a first plurality of articulated annular segments biased by spring means of a given strength and resilience, a central section and comprising a second plurality of articulated annular segments biased by spring means of greater strength and less resilience than the spring means of the distal end section, a relatively rigid annular proximal end section, a plurality of control wires secured at one end contiguous to said distal tip and passing through the first and second pluralities of articulated annular segments and said proximal end section, manually operable control means secured to the other ends of said control wires at the proximal end of the apparatus for manipulation of the distal end section, a first fiber optic system for transmitting light to the distal tip, a second fiber optic system for transmitting an image from the distal tip to the proximal end of the apparatus, said first and second fiber optic systems passing through the first and second pluralities of articulated annular segments and said annular proximal end section, a first conduit to selectively supply water and air to the distal tip, and an aspiration conduit having an inlet opening at the distal tip, said first conduit and said aspiration conduit passing through the first and second pluralities of articulated annular segments and said annular proximal end section.

2. An endoscope according to claim **1**, wherein said first plurality of articulated segments are interconnected by a plurality of springs, and a first group of said springs adjacent said distal tip being formed of finer wire than the remainder of said springs.

3. An endoscope according to claim **2**, wherein said springs are hairpin type springs having an arcuate configuration corresponding to the curvature of said first plurality of articulated annular segments.

4. An endoscope according to claim **1**, wherein said second plurality of articulated annular segments are interconnected by a plurality of wire coils secured within openings provided in the annular segments.

5. An endoscope according to claim **1**, wherein said second plurality of interconnected annular segments constituting the central section include segments adjacent the distal end section which are spaced from each other by a distance greater than the spacing between the segments adjacent the proximal end section.

6. An endoscope according to claim **1**, further comprising a housing secured to said proximal end section, an eye piece connected to said housing and operatively connected to said second fiber optic system, and said control wires passing through said housing to said manually operable control means.

7. An endoscope according to claim **6**, wherein said manually operable control means is a wobble plate, and said control wires being secured to said wobble plate at approximately equal spacings around the periphery of said wobble plate.

8. An endoscope according to claim **7**, further comprising guide means disposed around said control wires within said housing, and tubular means disposed around said control wires within said proximal end section.

9. Apparatus according to claim **1**, wherein said manually operable control means comprise a control ball provided with apertures of greater diameter than the diameter of said control wires, and manually actuatable means to lock said control wires to said control ball so that rotation of said control ball is effective to move said control wires and manipulate the distal end of the apparatus.

10. Apparatus according to claim **1**, further comprising control valve means operatively connected to said first conduit and said aspiration conduit and including a first pivotally mounted control lever having a foot pedal at one end and means adjacent the other end to normally prevent the flow of air to said first conduit, a second pivotally mounted control lever having a foot pedal at one end and having at the other end means to normally prevent the application of suction to said aspiration conduit, and a third pivotally mounted control lever having a foot pedal at one end and means adjacent the other end to normally prevent the flow of water to said first conduit, and spring means normally biasing said control levers to positions to prevent flow through said conduits.

11. In an endoscope having a distal end section, a central section and a proximal end section, control wires extending from the distal end section to control means at the proximal end section, means for the transmission of light to the distal end section, and means for the transmission of an image from the distal end section to the proximal end section, the improvement comprising said distal end section including a distal tip and a first plurality of articulated annular segments, spring means connecting each of said annular segments to the next adjacent annular segment and having a given strength and resilience, and said central section being comprised of a second plurality of articulated annular segments similarly connected by spring means having greater strength and less resilience than the spring means of the distal end section, said central section, said spring means comprising a plurality of individual spring members connected between each adjacent pair of said first plurality of articulated annular segments, each of said spring members having an arcuate configuration corresponding to the curvature of said first plurality of articulated annular segments.

12. An apparatus according to claim **11**, where the spring means of the central section comprise a plurality of wire coils secured to each of said segments within openings provided therein.

13. An apparatus according to claim **11**, wherein said spring members are hairpin type spring members and the number of spring members between each adjacent pair of said first plurality of articulated annular segment corresponds to the number of control wires.

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RICHARD A. GAUDET, Primary Examiner

C. L. PACE, Assistant Examiner

U.S. Cl. X.R.

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