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MICROMANIPULATING DEVICES

Filed April 9, 1954 3 Sheets-Sheet 1

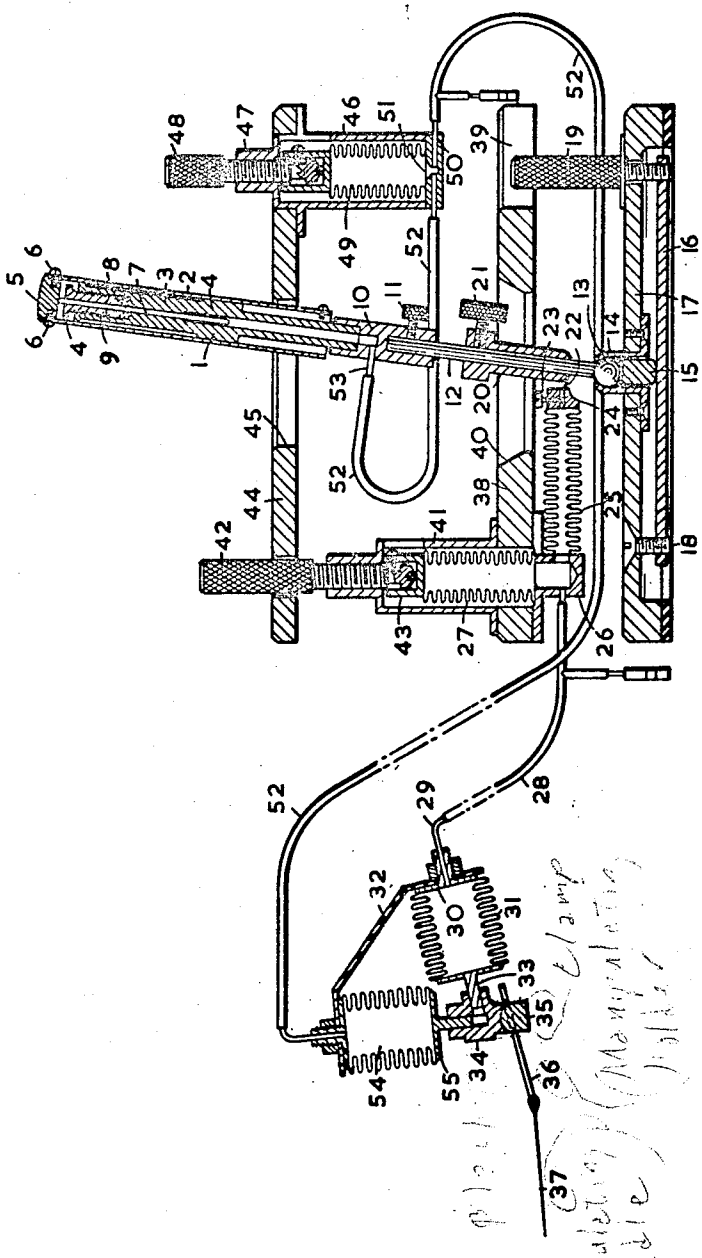


FIG. 1

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MICROMANIPULATING DEVICES

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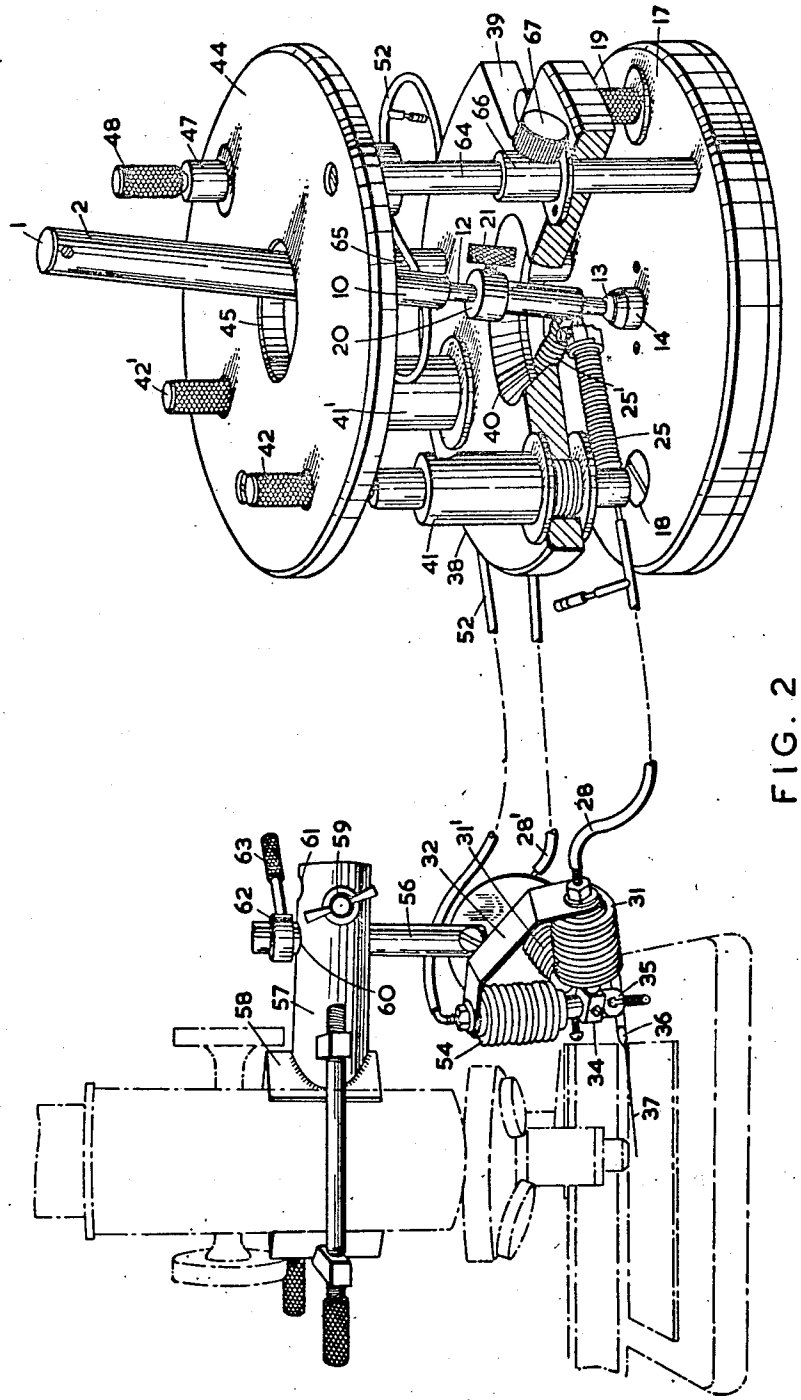


FIG. 2

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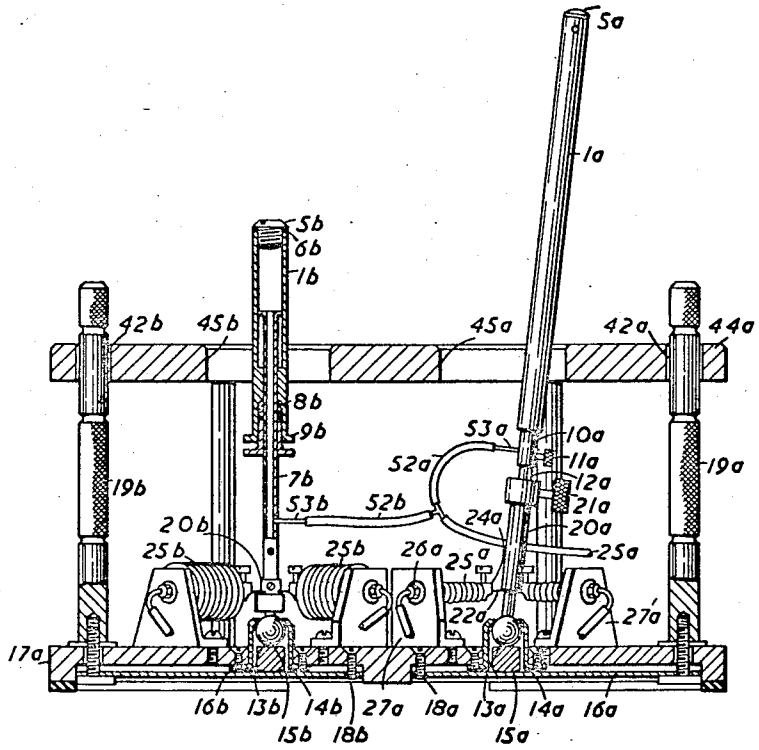


Fig. 3

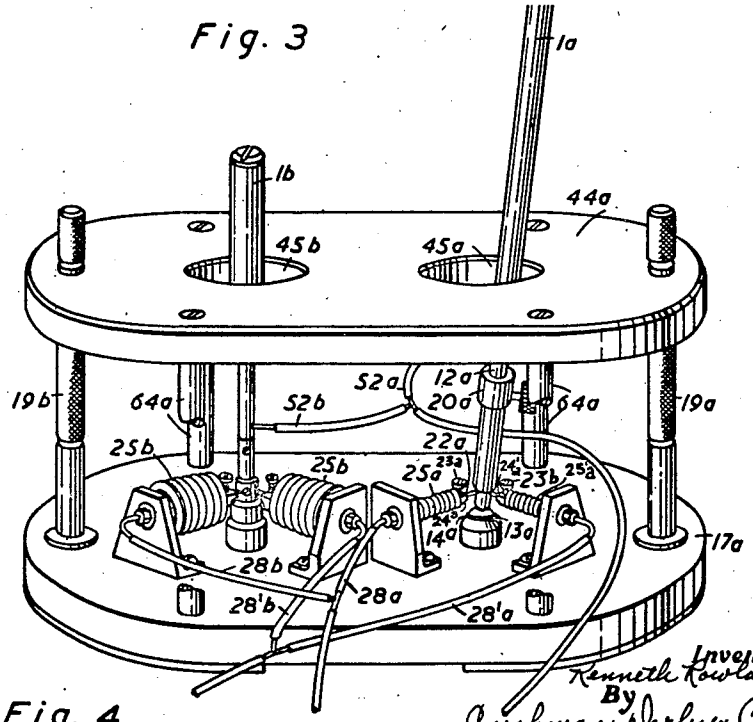


Fig. 4

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MICROMANIPULATING DEVICES

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Application April 9, 1954, Serial No. 422,233

Claims priority, application Great Britain April 11, 1953

4 Claims. (Cl. 88—40)

This invention relates to micromanipulating devices in which movement of a control member in a vertical, horizontal or transverse direction is transmitted on a reduced scale to a member adapted to be operated in the field of a microscope.

In the de Fonbrune type of micromanipulator the hand operated control lever is universally mounted and the unidirectional components of movement of the control lever are transmitted pneumatically to a manipulating head on a separate stand. Movement of the control lever in a longitudinal or transverse direction is arranged to operate two corresponding pistons working in cylinders disposed at right angles to one another, while rotation of a knob on top of the control lever causes vertical movement of a piston in a cylinder in the control lever, all three cylinders being connected by tubes to three deformable chambers mounted at right angles to each other in a frame provided with a holder to carry the manipulating member. It has also been suggested that the de Fonbrune type of apparatus can be operated hydraulically or electrically.

The object of the present invention is to provide a micromanipulator of improved and simplified construction which will be less expensive to produce than the known forms of such apparatus.

The present invention provides an improved micromanipulator apparatus of the kind in which movement of a hand operated control member is adapted to be transmitted to a manipulating member on a reduced scale, and which comprises three hydraulically operated bellows each adapted to actuate the manipulating member unidirectionally and arranged so that their longitudinal axes intersect at a common point and are inclined to one another at an angle of the order of 90 degrees, the said bellows being so connected to the manipulating member that the said manipulating member is supported solely by means of the said bellows.

The invention also comprises a control member associated with a pair of bellows arranged to transit hydraulically unidirectional components in a longitudinal and transverse direction of a rotational movement of the said control member to a corresponding pair of bellows adapted to actuate the manipulating member to reproduce the said movement of the said control member.

The control member is provided with an internal piston in a manner known per se for transmitting to the manipulating member movements in a vertical direction.

Additionally the fluid circuits from the control member to the head for operating the manipulating member in the vertical, transverse and longitudinal directions are each provided with a coarse adjustment in the form of a secondary bellows the closed ends of which are adapted to be adjusted whereby the manipulating member may be placed accurately in the desired initial operating position before the final movements are made by the control member.

Alternatively instead of providing a coarse adjustment bellows in each of the fluid circuits from the single control member to the head for operating the manipulating member in the vertical transverse and longitudinal directions an additional control lever may be used for providing coarse adjustments and this may be associated with a pair of coarse movement bellows so disposed that the components of movement in a longitudinal or transverse direction resulting from any movement of said coarse movement control lever are reproduced by the manipulating member through the bellows mounted in the head supported from the microscope which bellows also transmit the movements of the fine movement control lever in each of the longitudinal and transverse directions.

Preferably the coarse movement control lever is mounted together with the fine movement control lever on the same instrument base and each longitudinal and transverse direction operating bellows of the two pairs of bellows associated respectively with the fine and coarse movement control levers is connected by common longitudinal and common transverse direction operating fluid circuits leading to the head for operating the manipulating member in each of the longitudinal and transverse directions.

Identically constructed stiffness controls may be provided for each of the coarse and fine control levers to allow their ease of movement to be adjusted from completely free to locked positions.

In the accompanying drawings shown by way of example Figure 1 is a sectional elevation of an incomplete micro-manipulator, shown for purposes of description only.

Figure 2 is a perspective view of a partly sectioned hand control unit connected to a manipulating head shown clamped to the body tube of a microscope drawn in chain dotted lines.

Figure 3 is a sectional elevation and Figure 4 is a perspective view of an alternative construction of a micromanipulating hand control unit provided with both fine and coarse movement control levers.

Referring now to Figure 1, the micromanipulator hand control unit has a telescopic control lever **1** comprising a cylindrical sliding holder **2** which encloses an internally bored sleeve **3** having circumferential bearing surfaces **4**. The holder **2** is closed by a top flanged cap **5** which is located by set screws **6** passing through the holder wall and which carries a stainless steel piston **7** passing through a stuffing box comprising a packing material **8** and screwed gland **9**. The sleeve **3** is soldered to a coupling **10** bored longitudinally from either end to receive in its upper part the lower portion of the sleeve **3** and to hold in its lower part, by means of a screw **11** a rod **12** having a ball **13** forming part of a universal joint **14**. The ball **13** rests on the flat top surface of a block **15** which has a bevelled lower face bearing on an arm **16** anchored at one end to a circular base **17** of the control unit by a stud **18** and secured at the other to the stem of a knurled adjuster **19** screwed into the base **17**.

A collar **20** is slidably mounted on the lower portion of the rod **12** and is secured in an adjusted position by a screw **21**. A length of flat spring steel **22** is silver soldered at one of its ends to the lower rim of the collar **20** and is fixed at its other end by a screw **23** set in a slotted end block **24** which seals off one end of a light metal bellows **25**. This bellows is mounted substantially horizontal and is sealed at its other end to a connector **26** communicating with a stiffer vertical metal bellows **27** concentrically mounted above it, which connector **26** communicates through the length of flexible tubing **28** with a short bent stainless steel tube **29** which is silver soldered to a threaded boss on the end disc **30** of a metallic bel-

lows 31. The bellows 31 is secured at one end in a slot in a frame 32 and is sealed off at its other end by an end disc carrying a lug 33 anchored in a block 34. This block supports a clamp 35 in which is held, by means of a long knurled set screw, a manipulating holder 36 carrying a manipulating needle or such like member 37.

The vertical bellows 27 passes through a disc 38 mounted concentrically with the control base 17 and having a cut away portion 39 situated above the knurled adjuster 19 and a central aperture 40. This bellows 27 is enclosed by a flanged cylindrical housing 41 internally threaded along its upper portion to receive an adjusting plunger 42 bearing directly on a cup shaped member 43 which seals off the upper end of the vertical bellows which is arranged to be under slight compression when the plunger is at the top of its motion. The plunger 42 projects through a circular hand rest 44 concentric with the disc 38 and with the control base 17, the hand rest having a central aperture to accommodate the upper portion of the control column. A flanged cylindrical housing 46 is appended from the hand rest 44 and has a projecting portion 47 threaded internally to receive an adjusting plunger 48 which operates directly on the end closure of a vertical metal bellows 49 located within the housing. The base of this housing 46 is closed by an end diaphragm 50 bored diametrically to provide a conduit which communicates by means of the port 51 with the inside of the bellows 49 and which is connected by means of a length of flexible tubing 52, at one end to a connecting tube 53 passing into the coupling 10 and communicating with the bored column in the sleeve 3, and, at the other end to a second metallic bellows 54 mounted in a slot in the frame 32 and rigidly attached thereto so that a lug carried by its end disc 55 is secured into the block 34. The system comprising the bellows 25, the bellows 27, the flexible tubing 28 and the bellows 31 is filled with liquid.

Referring now to Figure 2, a second substantially horizontal metal bellows 25' is mounted at right angles to the first bellows 25 and is silver soldered at its closed inner end by a length of spring steel to the adjustable collar 20 and similarly connected at its outer end to a metal bellows mounted in a flanged housing 41' which supports a vertical adjusting plunger 42'. The connector at the base of the housing 41' communicates through the flexible tubing 28' with a metal bellows 31' fastened into the block 34 and mounted substantially at right angles to each of the manipulating head bellows 31 and 54 respectively. The frame 32 is supported by a column 56 passing through a tubular arm 57 projecting from a clamp 58 adapted to be mounted on a microscope barrel. The tubular arm 57 is split longitudinally from its outer edge along a portion of its length and carries transversely through it a threaded tightening bolt located on one side of the tube and threaded into a winged nut 59 bearing on the other side of the tube. This tightening bolt is positioned between seatings 60 and 61 drilled vertically through the tubular arm 57. The column 56 is passed through one of the seatings for its alternative positioning in the tubular arm and is secured in position by the winged nut 59. A collar 62 having a set screw 63 is adjustably fixed to the upper part of the supporting column 56 which projects through the tubular arm 57 and supports the said column on the arm.

Three equally spaced support columns, of which columns 64 and 65 only are shown in Figure 2, are positioned between the manipulator base 17 and the hand rest 44, the columns extending through the central disc 38 which is slidably mounted on and attached to one of the columns 64 by means of a collar 66 secured to the central disc 38 and adjustably held on it by a knurled head screw 67.

A T junction for evacuating and filling each system with liquid is provided in the hand control end of each length of flexible tubing 28, 28' and 52, connecting the manipulating bellows with its corresponding coarse adjustment bellows.

In using the micromanipulator, the control lever 1 is gripped so that the cylindrical holder 2 and the steel piston 7 can be caused to slide downwards relatively to the fixed inner sleeve 3 to produce a fluid pressure which is transmitted along the flexible tubing 52 to extend the metal bellows 54. This bellows extension imparts a downwards force on the block 34 and results in a similar motion of the manipulating holder 36. A uniplanar motion given to the control lever, by rocking it in the vertical plane containing the bellows 25, produces a compression or extension of the bellows and a proportionally greater or smaller fluid pressure is transmitted along the flexible tube 28 to the fluid contained in the metallic bellows 31 which is thus caused to expand or contract proportionately. This bellows movement is imparted through the block 34 and a corresponding movement of the manipulating holder is obtained. Similarly when the control column is moved in the vertical plane containing the bellows 25' a likewise movement is given to the manipulating holder in response to the axial movement of the manipulating head bellows 31'.

The three bellows 31, 31' and 54 are mounted substantially at right angles to each other and, because of the incompressibility of the fluid in the systems, maintain the manipulating holder with considerable rigidity in any position selected by the control lever movement. The control unit should be orientated and the bellows 25, 25' and 31, 31' connected up so that the motions of the manipulating needle, as seen in the reversed field of the microscope, follow exactly in all dimensions those of the hand. The control column is rotatable within a limited vertical cone of movement about the ball 13 which forms part of the universal joint 14. The pressure between the ball and its socket may be varied by rotating the knurled adjuster 19 which levers the sliding block 15 against the ball so that the control lever is arranged to move as easily or stiffly as required.

The sensitivity of the manipulator is varied by adjusting the position of the collar 20 on the lever rod 12 and at the same time moving the central disc 38 so that both bellows 25 and 25' are maintained approximately horizontal. The reduction in motion in the horizontal plane between a movement imparted at the top of the control lever and that conveyed to a manipulating member is the product of the ratio of the cross sectional areas of the manipulating and light bellows 31 and 25 respectively and the ratio of the lever height from the centre of the universal joint to the radius of the ball 13. For instance if the ratio of the cross sectional area of the manipulating bellows to that of the horizontal bellows is 4.2 then with the collar at the bottom of its travel and a ¼" diameter ball the reduction in movement between that of the top of the control lever at a height of 6" and that of the manipulating member is theoretically 4.2×48 which is approximately 200. The maximum degree of sensitivity is obtained when the collar 20 is in is lowest adjustable position on the rod 12 whilst the minimum sensitivity value is governed by the safe limit of extensibility of the horizontal bellows and this extensibility controls the variation in height of collar 20. When working at the least sensitive end of the range the bellows 25 and 25' exert an appreciable force tending to return the control lever to its central position and its movement therefore may need to be stiffened by rotating the knurled adjuster 19. In practice the control lever is most conveniently operated by holding it, as one would hold a pencil, rather below its upper end and this natural pencil grip permits delicately controlled movements and reproduces in the manipulating member, hand movements in the vertical as well as in the horizontal directions. Due to this form of grip and to the geometry of motion of the bellows 25 and 25' when the adjustable collar 20 is at its lowest position, a reduction ratio of

roughly 150 to 1 represents the maximum sensitivity of the manipulator normally obtained in use.

When the knurled plunger **42** is rotated it acts directly on the cup shaped member **43** so that the metal bellows **27** is compressed and the increased hydraulic pressure thus caused in the flexible tubing **28** imparts a corresponding movement to the manipulating holder. The adjusting plunger **42'** and **48** are similarly associated with vertical bellows mounted in the flanged housings **41'** and **46** and a depression of either of these plungers results in increased fluid pressures within the flexible tubes **28'** and **52** respectively and corresponding movements are transmitted to the manipulating holder. The compression of any of these vertical bellows imparts a coarse motion to the manipulating needle of about 1/16" of an inch in a corresponding direction and this action is independent of the control lever setting. The clamp **35** enables the manipulating holder to be angularly adjusted or moved in or out and the collar **62** and set screw **63** allow the whole manipulating head to be rotated without slipping down when the wing nut **59** is slackened off. The adjustment of the supporting column **56** for angular setting and height and if necessary of the clamp **35** brings the needle quickly into the view of a low power objective for subsequent precise centering by screwing the knurled plungers supported around the control lever.

It has been found that when the manipulating head bellows are orientated to be at 82½° to each other and a small tilt is given to the whole assembly (until the needle tip remains in the focal plane of the microscope over the whole field of view when the control lever is moved without altering the vertical motion), then a very small interaction only between the bellows is obtained and the motion of the needle follows very closely that of the control lever and gives an almost exact response to the lever movements over the whole field of the microscope, over any part of which, for example, one micron circles can be traced.

The combined use of the horizontal bellows **25** and **25'** and of the short lengths of spring steel **22** and **22'** eliminates all linkages otherwise necessary to accommodate the angular twist due to the rocking motion of the control lever, and needed to accurately transmit the small movements of its lower end. This angular twist is the only motion that the horizontal bellows cannot take up and in all other respects the bellows behave as if locked to the lower rim of the adjusting collar **20** and there is nothing in this movement which can possibly give rise to wear or backlash so that instantaneous response to the slightest hand movements is therefore obtained.

The elasticity of the housed bellows **27, 27'** and **49** is of such value that the bellows action takes up the backlash in the screw movements depressing them and returns them to their fully extended positions when their plungers are unscrewed, and in addition ensures that all volume changes in the horizontal bellows **25** and **25'** are taken up only by the volumetric changes in the extra flexible and manipulating head bellows and that no motion is lost through movement of the housed bellows, when motion is given to the control lever.

The microscope clamp gives a rough manual setting for the needle and allows the microscope body, objective and manipulating head to be racked up together so that for quick changing of micro-slides the body may be racked up or the stage lowered whilst the manipulating needle still remains in focus. In addition mounting the manipulating head firmly on the microscope barrel eliminates holder vibration which would be introduced by any lack of rigidity of the working bench or introduced by any holder support which would have to be otherwise used and provides means for using the microscope in the inverted position and at any desired angle which can be altered without disturbing the manipulating holder setting.

An improved clamping arrangement is obtained by having the tubular arm **57** telescopic so that a three dimensional movement may be given to the needle without having to adjust the clamp **35**. Also a replica of the tubular arm **57** could be attached to the part of the clamp on the other side of the microscope body so that two manipulating heads could be used simultaneously.

Referring now to Figure 3 which shows a hand control unit in which a coarse movement control lever and associated bellows is provided in place of the three plunger acted coarse movement bellows, the hand control unit has a fine telescopic control lever **1***a* having an inner sleeve (not shown) which is soldered to a coupling **10***a*. This coupling **10***a* is bored longitudinally from either end to receive in its upper part the lower portion of the sleeve and to hold in its lower part, by means of a screw **11***a* a rod **12***a* having a ball **13***a* forming part of a universal joint **14***a*. The ball **13***a* rests on the flat top surface of a block **15***a* which has a bevelled lower face bearing on an arm **16***a* anchored at one end to a base **17***a* of the control unit by a stud **18***a* and secured at the other to the stem of a knurled stiffness control **19***a* secured to the base **17***a*.

A collar **20***a* is slidably mounted on the lower portion of the rod **12***a* and is secured in an adjusted position by a screw **21***a*. A length of flat spring steel **22***a* is silver soldered at one of its ends to the lower rim of the collar **20***a* and is fixed at its other end by a screw **23***a* set in a slotted end block **24***a* which seals off one end of a light metal bellows **25***a*. This bellows is mounted substantially horizontal and is sealed at its other end to a connector **26***a* anchored to an angled support **27***a*, which connector communicates through the length of flexible tubing **28***a* (Figure 4) with a manipulating member bellows supported on a microscope barrel (not shown). A second bellows **25¹***a*, mounted substantially horizontal and at right angles to the bellows **25***a*, is similarly supported between the lower rim of the collar **20***a* and an angled support **27¹***a* and is connected by a length of flexible tubing **28¹***a* (Figure 4) with a second manipulating member bellows (not shown) forming part of the manipulating head supported on the barrel of a microscope. A length of flexible tubing **52***a* is connected at one end to a third manipulating member bellows (not shown) also forming part of the manipulating head and is connected at its other end to a tube **53***a* passing into the coupling **10***a* and communicating with a bored column in the sleeve (not shown) which is within the control lever **1***a* and in which slides a plunger (not shown) connected to a flanged cap **5***a* surmounting the control lever **1***a*.

A coarse control lever **1***b*, shorter and of a larger diameter than the fine control lever **1***a*, is closed by an end cap **5***b* and seal **6***b* and has an inner piston rod **7***b* which passes through a packing material **8***b* and a screwed gland **9***b*. The interior of this piston rod **7***b* communicates by means of a connection tube **53***b* and a length of flexible tubing **52***b* with the flexible tubing **52***a* leading to one of the manipulating bellows. The coarse control lever **1***b* passes through a collar **20***b* and terminates in a ball **13***b* forming part of a universal joint **14***b*. This ball **13***b* rests on the flat top surface of a block **15***b* which has a bevelled lower face bearing on an arm **16***b* anchored at one end to the base **17***a* by a stud **18***b* and secured at the other end to the stem of a knurled stiffness control **19***b*. The lever **1***b* is associated with a pair of bellows **25***b* and **25¹***b* which are of larger capacity than the corresponding bellows **25***a* and **25¹***a* associated with the fine control lever and which are connected by lengths of flexible tubing **28***b* and **28¹***b* to the lengths of tubing **28***a*, **28¹***a* respectively leading to corresponding manipulating member bellows. A hand rest **44***a* having apertures **45***a* and **45***b* to accommodate the upper portions of the fine and coarse levers respectively, is held above the base **17***a* by four supports **64***a* (Figure 4). Further apertures **42***a* and **42***b* in the hand rest **44***a* receive the knurled adjusters **19***a* and **19***b* respectively.

In using this alternative micromanipulator hand control unit the coarse control lever **1***b* is gripped so that the top portion of the lever is caused to slide relatively to the fixed piston rod **7***b* to produce a fluid pressure which is transmitted along the tube **52***b* to extend or contract the manipulating bellows **54** (Figure 2) which imparts a vertical motion to the manipulating member **37**. A uniplanar motion given to the coarse control lever by rocking it in either of the planes containing the bellows **25***b* or **25**[1]*b* produces a compression or extension of the bellows and a proportionately greater or smaller fluid pressure is transmitted along the tubes **28***b* or **28**[1]*b* respectively to the corresponding manipulating bellows. The coarse lever bellows **25***b* and **25**[1]*b* are of the same size as the manipulating bellows forming part of the manipulating head and the reduction ratio 10:1 approximately in movement of the coarse lever gives a range of manipulating member movement of 2 mm. in any direction. Thus by correctly positioning and extending or contracting the coarse control lever the manipulating member can be placed approximately in any desired position before it is finally manipulated by giving any necessary movement to the fine movement control lever.

Now by gripping the fine telescopic control lever **1***a* the top portion of the lever is caused to slide relatively to its inner sleeve (not shown) to produce a fluid pressure which is transmitted along the tube **52***a* to cause an extension or contraction of the manipulating bellows which imparts a vertical motion to the manipulating member. By rocking the lever **1***a* the bellows **25***a* and **25**[1]*a* are caused to extend or to contract and to transmit a proportionately greater or smaller fluid pressure within the corresponding flexible tubes **28***a* and **28**[1]*a* to alter the expansion of the manipulating bellows and to move the manipulating member accordingly.

The control units **1***a* and **1***b* are rotatable within the limited vertical cones of movement about the balls **13***a* and **13***b* forming part of the universal joints **14***a* and **14***b* respectively and the pressure between each ball and its respective socket may be varied by rotating the knurled adjusters **19***a* and **19***b* which lever each of the sliding blocks **15***a* and **15***b* respectively against its adjacent ball so that the control levers may be arranged to move as easily or stiffly as required.

The sensitivity of the fine manipulating control is varied by adjusting the position of the collar **20***a* on the lever rod **12***a*. This permissible vertical movement of the collar **20***a* without unduly stretching the fine bellows **25***a* and **25**[1]*a* is about ½" and this vertical collar movement enables the fine control lever to have a reduction ratio between 40:1 and 300:1.

For case of replacement of the springs connecting the bellows **25***a* and **25**[1]*a*, and **25***b* and **25**[1]*b* with their corresponding control members it is of advantage to screw the inner capped ends of the bellows over lugs projecting from the lower parts of the collars **20***a* and **20***b* and to have side connections to each bellows to allow their outer closed ends to be attached by lengths of flat spring steel to the angled supports **27***a*, **27**[1]*a* and **27***b*, **27**[1]*b* so that when the control levers are positioned vertically the bellows can be set more easily in positions of neutral tension.

It will be noted that in both the embodiment illustrated in Figures 1 and 2 and the embodiment illustrated in Figures 3 and 4, the hydraulic devices of the means for effecting coarse adjustment are connected by hydraulic lines to the respective hydraulic lines leading from the hydraulic devices of the control member to the hydraulic devices of the manipulating member. Thus, the hydraulic devices of the coarse adjustment means are connected in parallel respectively with the hydraulic devices of the fine adjustment means in each embodiment. The utilization of the term "paralllel" to describe the connection of the devices in the entire hydraulic system is conventional in the hydraulic system art.

I claim:

1. In a micromanipulator having a manually operated control member mounted for movement in three dimensions and a manipulating member mounted so as to reproduce on a reduced scale the movements of said control member; means for transmitting the movements of the control member to the manipulating member including three similar hydraulically operated bellows each arranged to actuate the manipulating member unidirectionally, said bellows being disposed with their longitudinal axes intersecting at a common point and inclined with respect to each other at an angle of approximately ninety degrees, a fixed mounting for the end of each of the three bellows remote from said common point, and a rigid holder constituting the sole support for the manipulating member rigidly secured to the end of each one of the three bellows adjacent said common point so as to secure the ends of said bellows adjacent said common point rigidly together whereby longitudinal extension and contraction of any one of the bellows is substantially accommodated by lateral distortion of the other two by relative lateral movement between the ends thereof.

2. A micromanipulator apparatus comprising a hand operated control member movable in three dimensions, three fluid-pressure expansible and contractible fine transmitting devices operatively connected with said control member for actuation thereby, corresponding fluid-pressure expansible and contractible receiving devices operatively connected with said fine transmitting devices for actuation thereby, a manipulating member operatively connected with said receiving devices for actuation thereby so that movement of said control member in any direction is reproduced on a reduced scale in said manipulating member, and three fluid-pressure expansible and contractible coarse transmitting devices operatively connected in parallel respectively with said three fine transmitting devices for imparting an initial coarse movement to said manipulating member to produce a preliminary coarse adjustment of the position of said manipulating member.

3. Apparatus as defined in claim 2 wherein said coarse transmitting devices are operatively connected with a coarse hand operated control member for actuation thereby.

4. Apparatus as defined in claim 2 wherein each of said coarse transmitting devices is provided with a separate means for actuating the same independently of the other two.

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