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(51) International Patent Classification 6 : G01L	A2	**(11) International Publication Number:** WO 96/21849 **(43) International Publication Date:** 18 July 1996 (18.07.96)

(21) International Application Number: PCT/US95/16957

(22) International Filing Date: 28 December 1995 (28.12.95)

(30) Priority Data:
08/365,828 29 December 1994 (29.12.94) US

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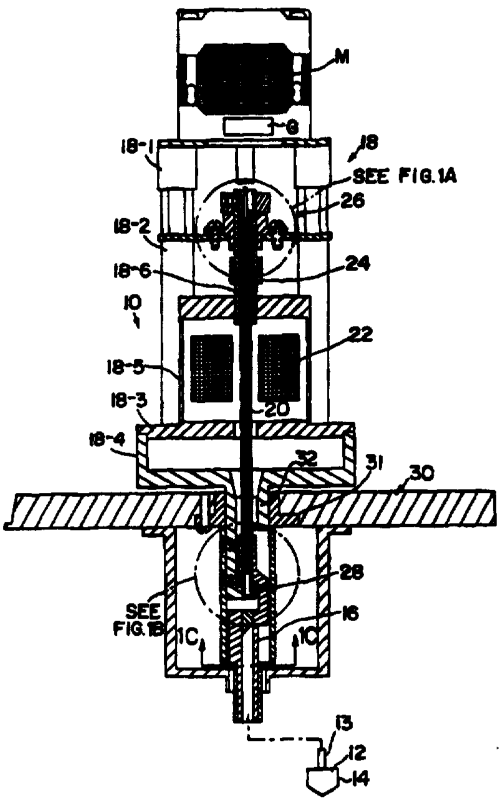
(81) Designated States: BR, CA, CN, JP, KR, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published
Without international search report and to be republished upon receipt of that report.

(54) Title: SUPPORT SYSTEM WITH RADIALLY RIGID WIRE SUSPENSION

(57) Abstract

The invention comprises measuring or responsive instruments, including (but not limited to) viscometers, having a music wire (20) or like high tensile wire support between driving/driven shaft assemblies (18, 16) and appropriate mounting to eliminate drag, friction, radial misalignment, vibration problems, especially at high rotational speeds, and afford an enhanced accuracy and speed of measurement or other response of the instrument as a whole, including such specific features allowing large angular deflections or small ones (full scale under one degree) and axial and radial rigidity. The instrument can also be used with a plate for cone plate, oscillation and normal force measurements.



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SUPPORT SYSTEM WITH RADIALLY RIGID WIRE SUSPENSION

BACKGROUND OF THE INVENTION

The present invention relates to instrument systems for measuring rotational torque and is characterized by a rigid axial and radial support for the torque interconnect element.

State of the art torque interconnects such as coiled springs suffer high speed and rotational forces and weak radial alignment from significant errors introduced by wire stretching and frictional drag. Some examples of state of the art instruments are the DV-2, 3 viscometers of Brookfield Engineering Laboratories, Inc., Stoughton, Massachusetts, U.S.A.

It is an object of the invention to overcome such difficulty.

It is a further object to provide a very high speed capability.

It is a further object of the invention to accomplish tight alignment.

It is a further object of the invention to minimize or eliminate rotational friction in a rigid support structure.

It is a further object of the invention to provide a means for dampening vibrations; such vibrations can prove detrimental to the torsional accuracy of such torsion systems.

SUMMARY OF THE INVENTION

The invention comprises measuring or responsive instruments, including (but not limited to) viscometers, having a music wire (20) or like high tensile wire support between driving/driven shaft assemblies (18, 16) and appropriate mounting to eliminate drag, friction, radial misalignment, vibration problems, especially at high rotational speeds, and afford an enhanced accuracy and speed of measurement or other response of the instrument as a whole, including such specific features allowing large angular deflections or small ones (full scale under one degree) and axial and radial rigidity. The instrument can also be used with a plate for oscillation and normal force measurements.

The invention provides a wire torsion mount of high tensile strength, e.g. music wire, a hardened steel wire with a tensile strength of 90,000 psi with an elastic modulus (E) of 27.6 x 10^6 psi and shearing modulus (G) in torsion of 10.6 x 10^6 psi. However, the invention is applicable broadly to wires with E & G values sufficiently high to provide axial support while allowing significant elastic deformation in torsional rotation. The wire avoids permanent axial deformation even when supporting axial loads of 10 pounds or more (typically 2-4 pounds in the following context of the next paragraph, but other loads in other contexts).

In the viscometer context, wires of .003 --- .025 inch diameter wires are used, typically .006 inch or .012. Such a wire is mounted at the center of rotation of a rotational drive system of a viscometer and because of its small diameter and relatively long length (typically two inches in relation to a .012" diameter wire and generally over 100:1 length to diameter), has low rotational torque and essentially no centrifugal force even when rotated at high speeds. A range of torque of 0 to 10,000 dyne-cm (typically, about 7,000) is realized over a full scale angular deflection range of 45 to 90° (typically about 75°). The wire is surrounded near or at each end by a jewel bearing for radial support, thereby assuring accurate concentric alignment of the rotational drive system. Radial deflection tendencies of the torsion assembly are substantially counter-acted by the bearing. The foregoing length to diameter considerations can be modified in certain situations, e.g. the multiple wire arrangements of certain embodiments described below. Small deflection angles can be generated using shorter lengths and/or lower length to diameter ratios (i.e. over 50:1). The smaller angle allows a lower stiffness and/or a higher sensitivity at a given stiffness or a combination of these factors.

Other objects, features and advantages will be apparent from the following detailed description of preferred embodiments taken in conjunction with the accompanying drawings in which:

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a cross-section view of a preferred embodiment of the invention;

FIGS. 1A and 1B are expanded sectional views of upper and lower mount portions thereof and FIG. 1C is a lateral cross-section view taken as indicated at C-C in FIG. 1;

FIG. 2 is a cross-section view of another preferred embodiment utilizing multiple linked wires, FIGS. 2A, 2B and 2C as applied to FIG. 2 correspond to FIGS. 1A, 1B, 1C and FIG. 1D is an expanded view of the wire link.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

FIG. 1 shows a viscometer instrument 10 comprising a rotational driven member 12 (spindle) with a measuring surface 14 and a support shaft 16 for interaction with the fluid to be measured. A motor M and gearing G provide high speed rotational drive to a device assembly 18 which is interconnected to the support shaft not by the usual calibrated spiral spring but rather by an elongated 2-6 inch, typically 4 inch, wire 20 made of high strength wire material, or the like, as described above. A non-limiting example of such wire is the wire type known as music wire. The effect of viscosity of a fluid encountered by the element 12 is to cause a twist of the wire 20 over an angular range of approximately 80° full scale. A read out transducer or other display or conversion device can be provided as indicated at 22, using slip rings at 24, to measure to within .001 or better of full scale deflection. More angular deflection allows greater sensitivity. However, it is imperative to keep the deflection well within the pure elastic range of the wire material.

The wire is held in mounting pins P between a top mount 26 and bottom mount 28. The top mount, shown in FIG. 1A includes a set screw 26-1 which can be loosened and retightened for setting a zero angle setting. A block (26-2) locked to the drive train acts as a non-destructive clamp for the upper end of the wire assembly. A ring 26-3 is glued or fitted to the wire to act as a stop for axial positioning and control of upward movement of shaft 20-1, typically limiting movement to .003-005". The bottom mount (FIG. 1B) comprises the music wire pressed in a .062" diameter pin P with an appropriate bore to receive the wire. A rotatable tube 20-1 surrounds and is rotatably held with wire 20 due to the nature of the top and bottom mounts. The annulus (20-2) between the wire and tube can be filled with a damping fluid (e.g. a high viscosity silicone oil or similar fluids).

A fixed structure plate 30 of the instrument accommodates a necked down section 32 of the rotating assembly for rotation within a bearing or bushing 31.

The rotating assembly as a whole has an axially and radially rigid suspension, does not require axial bearings for the critical wire 20 or tube 20-1 (bushing 31 does not detract from sensitivity) and is a breakthrough in sensitive suspension design. The top and bottom mounts of the wire hold it rigid radially, but do not interfere circumferentially and provide for rigid and substantial axial support.

Because tube 7 surrounds sensing shaft 16 and is connected rigidly to the driven shaft 18-4, the non-symmetrical section of the rotating sensing shaft assembly is covered by likewise rotating portions thereby eliminating air turbulence and windage effects at high rotational speeds.

As mentioned above the torsional assembly, as a whole, is useful in viscometers and other instruments (e.g. dial displays of volt-meters, ammeters and other electrometers), magnetism sensors and torque sensors in general and in non-instrument contexts (e.g. motors for clockwork, displays, vane supports pointers). The latter is a driven (tubular) shaft locked to shaft 16 at the lower end. The drive or driver components include 18-1, 18-2, 18-3, 18-4 all driven directly by M/G and driving shaft 16 subject to angular deflection therebetween taken up at twisted wire 20.

The further preferred embodiment of an instrument 10' shown in FIGS. 2, 2A, 2B, 2C, 2D is identical to the FIG. 1 embodiment with the important difference that the wire 20 is subdivided into sections 20A, 20B with meeting ends fixed in a middle pin P'. This arrangement has the advantage that both ends of the support wire assembly are fixed to the driven portion 18-4 with the wire jewel bearing supports mounted on the sensing shaft 20-1. Axial play is thus totally eliminated with no loss in sensitivity or increase in friction. However, this arrangement does provide greater rotational stiffness and will require smaller wire sizes and/or lesser angles of deflection for full scale. One major advantage herein is it enables a rheogram instrument providing quick, continuous tracking of rheological properties at varying rotational speeds without the need for settling in time at each new speed setting. For a given wire diameter halving the length (dividing it in two as shown at FIG. 2D) affords a 4x stiffness enhancement. The wire assembly of FIG. 2 flexes, but is fully locked against axial movement (compared to slight axial play in FIG. 1).

It will now be apparent to those skilled in the art that other embodiments, improvements, details, and uses can be made consistent with the letter and spirit of the foregoing disclosure and within the scope of this patent, which is limited only by the following claims, construed in accordance with the patent law, including the doctrine of equivalents.

What is claimed is:

CLAIMS

1. A suspension system instrument with a measuring element support shaft and drive shaft combination driven by a prime mover, characterized in that the support shaft and driver shaft are interconnected by a wire of such small diameter and long length (relative to diameter) such that it provides low torsional resistance yet still has sufficient tensile strength to support loads up to five pounds without permanent deformation, said wire having an end fixed to each of the support and driven shafts and including a means for supporting and radially aligning the wire at each end via the unattached shaft.

2. The instrument of claim 1 where the wire torsional modulus and wire diameter are such as to provide a torsional resistance over an angle of 45° or more, under 10,000 dyne-cm.

3. The instrument of claim 1 wherein the wire torsional modulus and wire diameter are such as to provide a torsional resistance over an angle of less than 45° under 10,000 dyne cm.

4. The instrument of claims 3 wherein the wire torsional modulus and wire diameter are such as to provide a torsional resistance over an angle of less than 2° under 10,000 dyne cm.

5. The instrument of any of claims 1, 2, 3 or 4 constructed and arranged as a viscometer.

6. The instrument of claims 1 or 2 wherein means are provided for establishing a fixed and controlled relative positioning of the sensing and driving shaft member axially and wherein said means establishes preferred spacing axially between said shafts to limit axial movement of the support shaft in the wire compression sense.

7. The instrument of claim 6 constructed and arranged as a viscometer.

8. The instrument of claim 7 wherein the wire has an extension beyond the driven fixing means and wherein the driven fixing means is reclampable to allow the extension to be used for the relative rotational positioning of the support shaft and the driving shaft for signal nulling and/or providing rotational stops adjustment capability.

9. The instrument of claim 1 wherein the wire has an extension beyond the driven fixing means and wherein the driven fixing means is reclampable to allow the extension to be used for the relative rotational positioning of the support shaft and the driving shaft for signal nulling and/or providing rotational stops adjustment capability.

10. The instrument of either of claims 1 or 9 comprising means surrounding the support shaft and connected rigidly to the driven shaft such that the non symmetrical section of the support shaft is completely covered by likewise rotating portions thereby eliminating air turbulence and windage effects at high rotational speeds.

11. The instrument of claim 6 comprising means surrounding the support shaft and connected rigidly to the driven shaft such that the non symmetrical section of the support shaft is completely covered by likewise rotating portions thereby eliminating air turbulence and windage effects at high rotational speeds.

12. The instrument of claim 7 comprising means surrounding the support shaft and connected rigidly to the driven shaft such that the non symmetrical section of the support shaft is completely covered by likewise rotating portions thereby eliminating air turbulence and windage effects at high rotational speeds.

13. The instrument of any of claims 1, 2, 3 or 9 wherein a damping fluid is provided between the support shaft and the wire to reduce vibration and

noise on the wire at high rotational speeds and/or from rough driving means.

14. The viscometer of claim 5 wherein a damping fluid is provided between the support shaft and the wire to reduce vibration and noise on the wire at high rotational speeds and/or from rough driving means.

15. The viscometer of claim 8 wherein a damping fluid is provided between the support shaft and the wire to reduce vibration and noise on the wire at high rotational speeds and/or from rough driving means.

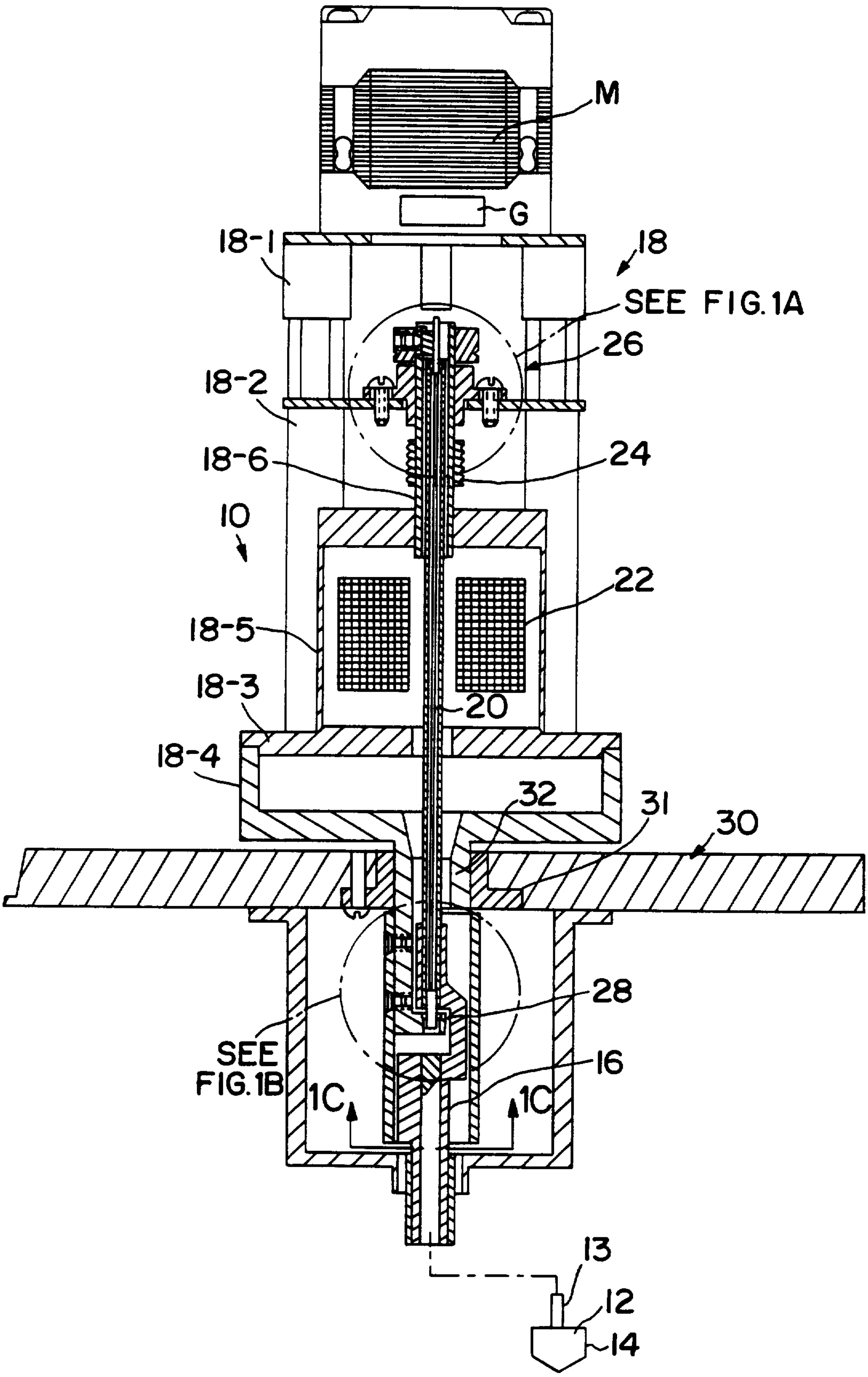
M
G
18-1
18
SEE FIG.1A
26
18-2
18-6
24
10
22
18-5
18-3
20
18-4
32
31
30
28
SEE FIG.1B
16
1C
1C
13
12
14

FIG.1

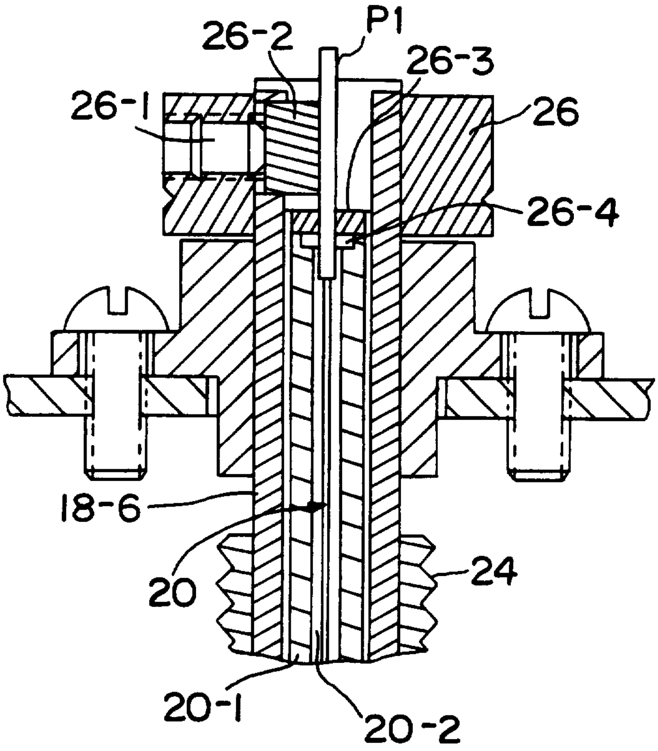

FIG. 1A

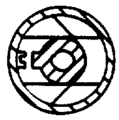

FIG. 1C

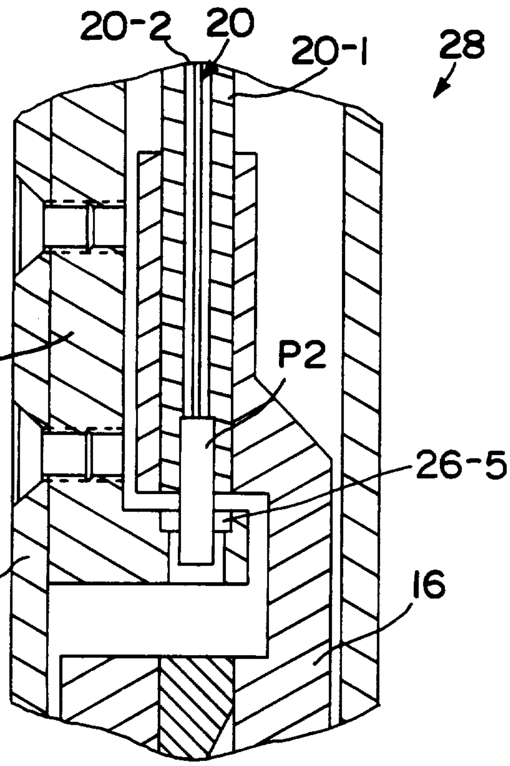

FIG. 1B

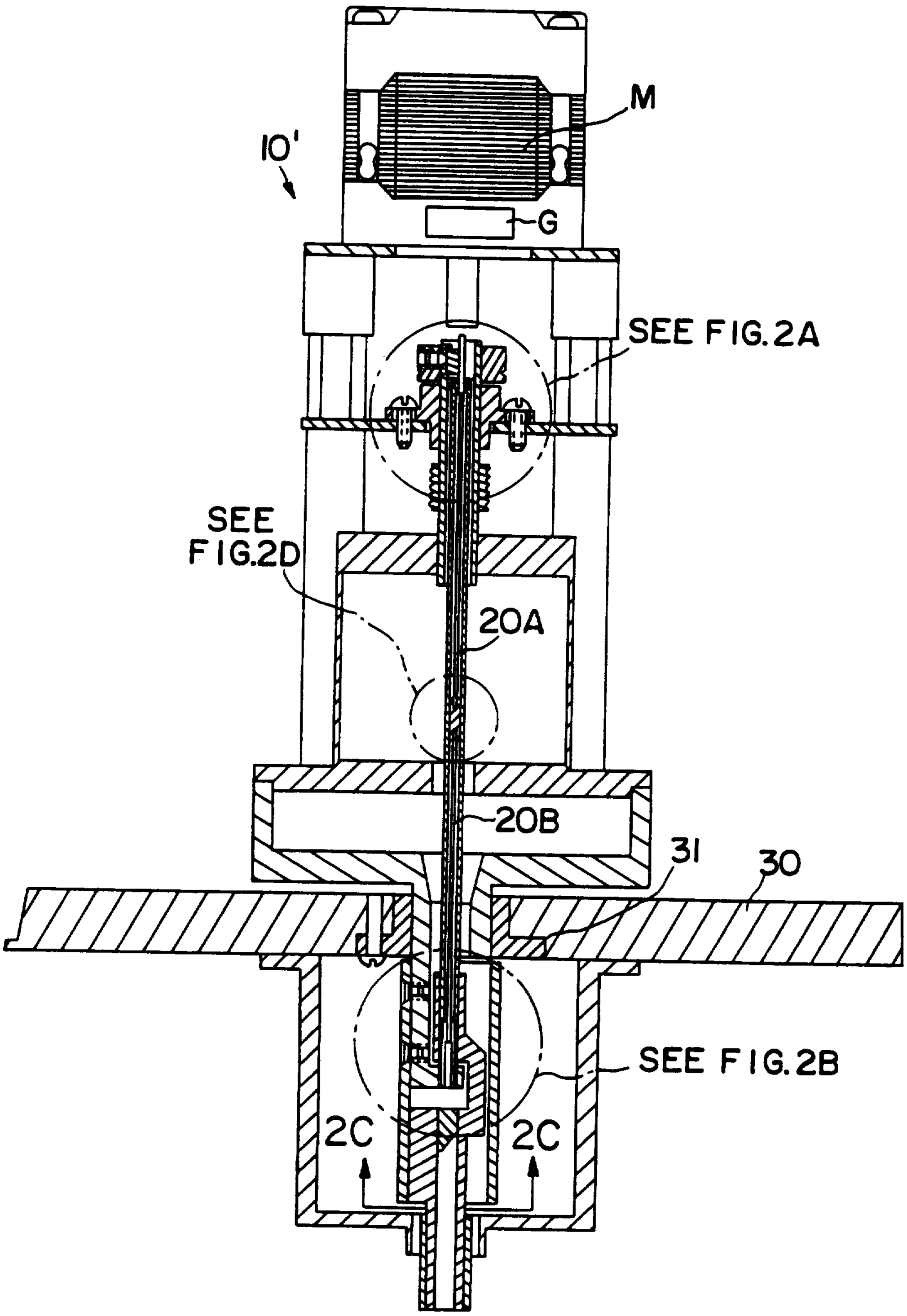

FIG.2

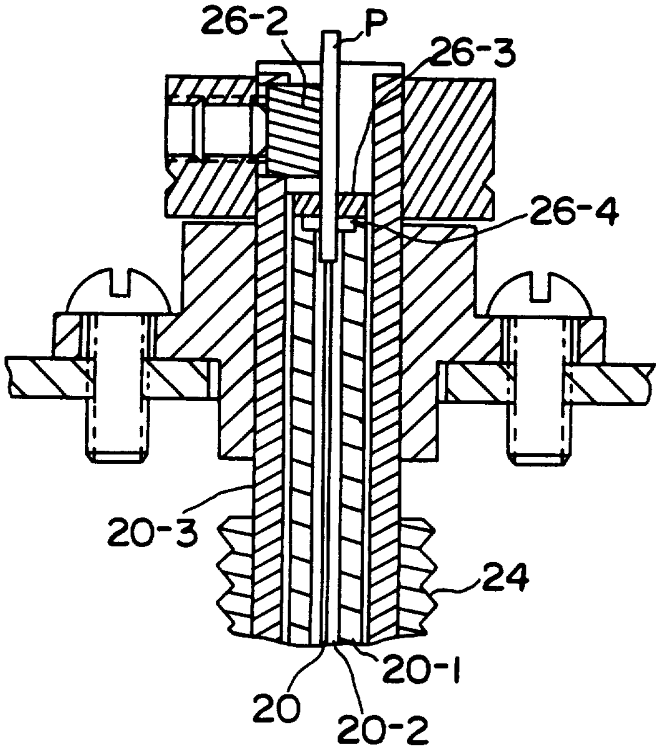

FIG. 2A

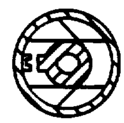

FIG.2C

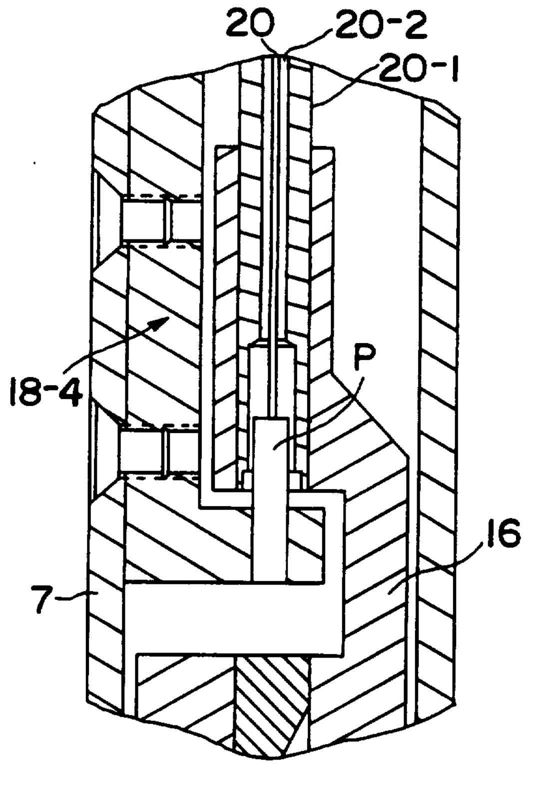

FIG.2B

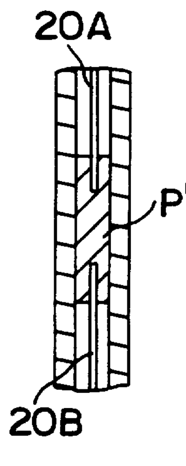

FIG.2D