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(54) Downhole mud diverter tools

(57) A downhole fluid diverter tool (10) has an axial through-bore (13) and fluid passages (18) extending through its side wall. Normally-closed pressure-actuated valve means (20) are located in the fluid passages whereby a proportion of a flow of drilling fluid passing through the cylindrical body may be diverted through the fluid passages (18) by increasing the fluid pressure in the interior of the tool such that the valve means (10) open. Each valve means (20) includes a piston member (28) housed in the side wall and movable in a direction parallel to said longitudinal axis so as to open and close said fluid passage. Each piston member (28) is slidably located in a bore which extends parallel to the longitudinal axis of the tool, said bore having a concave end surface (36), said fluid passage intersecting said concave end surface, said piston member (28) having a generally convex complementary end surface adapted to seat against said concave end surface so as to close said fluid passage, and said valve means further including bias means for urging said convex end surface of said piston (28) into engagement with said concave end surface (36) of said bore. The valve means (20) comprises a housing adapted to be located in a pocket formed in the exterior surface of the body of the tool (10).

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Description

[0001] The present invention relates to downhole tools for use in the drilling of oil wells and the like, for diverting a portion of the flow of drilling fluid (mud) through a drill string out of apertures formed in the tools, which form part of the drill string, for the purpose of assisting in the clearance of cuttings from the annulus around the drill string. The invention is applicable particularly, but not exclusively, to high angle or horizontal long-reach wells.

[0002] In the drilling of oil wells or the like, cuttings from the drilling operation are flushed back to the surface of the bore by drilling fluid which circulates down through the interior of the drill string and returns to the surface through the annulus around the drill string. In high angle or horizontal wells, difficulties are often experienced in effecting adequate flushing of such cuttings.

[0003] In order to alleviate such problems, it is known to deploy a circulating sub in the drill string. A circulating sub is simply a cylindrical sub having an aperture formed in its side through which drilling fluid is diverted out to the annulus around the drill string for flushing cuttings. The sub is plugged at its lower end in order to divert the fluid, so that drilling operations have to be interrupted while the circulating sub is deployed. Circulating subs of this type also have a limited life owing to erosion by the abrasive fluid.

[0004] WO96/04458 discloses an improved diverter tool ("diverter sub") in which drilling fluid is diverted by means of normally-closed pressure-actuated valves located in apertures in the sides of the tool. The diversion of said drilling fluid is effected by increasing the fluid pressure in the interior of the cylindrical body such that the valve means open and a proportion of the drilling fluid exits from the cylindrical body through the apertures. This enables the tool to be incorporated into the drill string during normal drilling operations and to be actuated by means of increasing the fluid pressure inside the drill string whenever drilling fluid is required to be circulated through the apertures in the sides of the tool.

[0005] The valves each comprise a nozzle holder mounted in the aperture in said cylindrical body, a nozzle slidably mounted in the nozzle holder and having a fluid passage formed therethrough and resilient bias means adapted to urge the nozzle in a direction towards the interior of said tool so as to close the fluid passage. The nozzle is adapted to move against the force of the resilient bias means in an outward direction, in response to a predetermined fluid pressure within the interior of the tool, so as to open the fluid passage.

[0006] This valve arrangement relies on movement of the nozzle in a direction normal to, or at an angle to, the longitudinal axis of the tool. Accordingly, the tool requires a certain minimum wall thickness to accommodate the valve arrangement. For this reason, the tool requires a certain minimum outside diameter, typically of at least about 20 cm (8 inches).

[0007] It is a first object of the present invention to provide an improved fluid diverter tool with pressure actuated fluid diverter valves which can be accommodated in a relatively small wall thickness and which, therefore, are suitable for use in tools having relatively small outside diameters.

[0008] In accordance with the invention there is provided a downhole fluid diverter tool comprising: a generally cylindrical body having a longitudinal axis and an axial through-bore and adapted for connection within a drill string, said body having at least one fluid passage extending through a side wall thereof; and at least one normally-closed pressure-actuated valve means associated with said at least one fluid passage whereby a proportion of a flow of drilling fluid passing through the cylindrical body, in use, may be diverted through said at least one fluid passage by increasing the fluid pressure in the interior of the cylindrical body such that said valve means opens and a proportion of the drilling fluid exits from the cylindrical body through said at least one fluid passage; wherein said valve means includes a piston member housed in said side wall and movable in a direction substantially parallel to said longitudinal axis so as to open and close said fluid passage.

[0009] Preferably, said piston member is slidably located in a bore which extends substantially parallel to said longitudinal axis, said bore having a concave end surface, said fluid passage intersecting said concave end surface, said piston member having a generally convex complementary end surface adapted to seat against said concave end surface so as to close said fluid passage, and said valve means further including bias means for urging said convex end surface of said piston into engagement with said concave end surface of said bore.

[0010] Preferably, said fluid passage comprises a first portion connecting said through-bore to the bore of said valve means and a second portion connecting the bore of said valve means to an outlet aperture on the exterior surface of the tool.

[0011] Preferably, said valve means comprises a housing adapted to be located in a pocket formed in the exterior surface of the body of the tool, said bore and said fluid passage being formed in said housing.

[0012] Preferably, said housing and said piston member are formed from erosion resistant material, more preferably a ceramic material and most preferably alumina.

[0013] The tool preferably further includes an insert member extending through the wall of the tool body between a bottom surface of the valve pocket and the through-bore of the tool body, and having a through-passage formed therein and aligned with the first portion of said fluid passage.

[0014] Preferably, said insert member is also formed from erosion resistant material, more preferably a ceramic material and most preferably alumina.

[0015] Embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawings in which:

Fig. 1 is a perspective view of an example of a diverter tool ("sub") embodying the invention;

Fig. 2 is a schematic, sectional side view of a main body portion of the tool of Fig. 1;

Fig. 3 is a transverse sectional view of the tool of Fig. 1;

Fig. 4 is a schematic sectional view of the main body portion of the tool of Fig. 1;

Fig. 5 is a schematic sectional side view of a valve assembly forming part of the tool of Fig. 1;

Fig. 6 is a schematic sectional side view of a housing forming part of the valve assembly of Fig. 5;

Fig. 7 is a top view of the housing of Fig. 6;

Fig. 8 is a schematic sectional side view of a piston member forming part of the valve assembly of Fig. 5;

Figs. 9A and 9B are, respectively, schematic sectional side and end views of a plug member forming part of the valve assembly of Fig. 5;

Figs. 10A and 10B are, respectively, schematic top and sectional side views of a pocket formed in the main body of the tool to accommodate the valve assembly of Fig. 5; and

Figs. 11A, 11B and 11C are, respectively, schematic bottom and sectional side and front views of a locator member associated with the valve assembly of Fig. 5 and the pocket of Fig. 10.

[0016] Referring now to the drawings, Fig. 1 is a perspective view of a first embodiment of a fluid diverter tool 10 in accordance with the present invention. Fig. 2 is a sectional side view of a main body portion 12 of the tool 10. The tool 10 comprises a slick sub having a generally cylindrical body portion 12. The body 12 has a central through-bore 13 and is adapted for connection within a drill string by any suitable means such as an internally threaded box 14 and an externally threaded pin 16. The tool 10 has a plurality of fluid apertures 18 spaced along its length, preferably disposed along a helical path. In the example illustrated, there are three apertures 18, successive apertures 18 being angularly displaced 120 degrees from one another around the circumference of the body 12. However, the number of apertures 18 may be varied and the pitch of the helical path may be varied so that the angular displacement between successive apertures 18 is other than 120 degrees.

[0017] The apertures 18 comprise the outlets of valve assemblies 20 located in generally rectangular pockets 22 formed in the outer cylindrical surface of the body portion 12. Fig. 2 shows the pockets 22 arranged in-line for clarity, so as to illustrate their spacing along the length of the body 12. Fig. 4 shows the actual angular positions of the pockets 22 displaced from one another around the circumference of the body 12. Each of the pockets 22 includes an aperture 24 extending between the floor of the pocket 22 and the interior of the body 12 whereby the interior bore 13 of the body 12 communicates with the valve assemblies 20 and hence with the outlet apertures 18.

[0018] The valve assembly 20 is illustrated in detail in Figs. 5 to 9 and comprises a housing 26, a piston member 28, a retaining plug 30 and a spring or other resilient bias means 32.

[0019] The housing 26 is configured to fit within the pocket 22, extending in the fore-and-aft direction relative to the body 12 of the tool 10. The outer surface of the housing is part-cylindrical (convex) in transverse cross section to match the outer surface of the body 12 (see Fig. 3). The housing 26 includes a blind bore 34 extending from the forward end of the housing 26 (the left hand end as seen in Figs. 5 and 6) towards its rearward end. The bore 34 terminates in a concave (preferably part-spherical) surface 36, forming a valve seat as shall be described below. In use, the bore 34 extends substantially parallel to the longitudinal axis of the tool 10.

[0020] A first fluid passage 38 extends from the bottom surface of the housing 26 substantially at right angles thereto and intersects the concave surface 36 on the innermost side thereof. An annular groove 40 is formed in the bottom surface of the housing 26, surrounding the fluid passage 38, to accommodate a first O-ring 42. When the housing 26 is located in the pocket 22, the first fluid passage 38 is co-axial with the aperture 24. A second fluid passage 44 extends from the outermost side of the spherical surface 36 to the outlet aperture on the outer surface of the housing 26. The angle of the second fluid passage 44 with respect to the longitudinal axis of the bore 34 determines the angle of a fluid jet exiting the aperture 18 in use of the tool 10. In this example, the second fluid passage 44 extends rearwardly at an angle of 30 degrees.

[0021] The housing 26 further includes a transverse bore 46 extending across its width adjacent the forward end thereof and intersecting the bore 34. The transverse bore serves for securing the retaining plug 30 as shall be described below. The housing 26 is secured in the pocket 22 by any suitable means such as bolts extending through the housing 26 from the outer surface thereof and into the floor of the pocket 24.

[0022] The piston member 28 comprises a head portion 48 and a shaft portion 50. The head portion 48 is a close fit inside the bore 34 of the housing 26 and has a convex (preferably part-spherical) end portion 52, of complementary shape to the concave end surface 36 of the bore 34. A groove 54 is formed around the circumference of the head portion 48 forward of the convex portion 52 to accommodate a second O-ring 56. The piston 28 is slidable within the bore 34 and a fluid seal is formed between the head 48 of the piston and the interior of the bore 34. When the piston is in its normal position (as shown in Fig. 5), the convex portion 52 of the piston head 48 seats against the concave surface 36 of the housing bore 34, closing the fluid passages 38 and 44.

[0023] The shaft 50 of the piston 28 is of lesser diameter than the head 48, such that an annular shoulder 58 is formed therebetween.

[0024] The retaining plug 30 is generally cylindrical and fits within the end of the bore 34 of the housing. The plug 30 has a transverse bore 60, which is aligned with the transverse bore 46 of the housing 26 so that the plug 30 may be retained in position within the bore 34 by means of a pin or the like 62 extending therethrough.

[0025] The piston is biased towards its normal position (illustrated in Fig. 5) by the spring 32, which surrounds the piston shaft 50 and is retained between the shoulder 58 of the piston 28 and the retaining plug 30.

[0026] A generally cylindrical locator member or insert 64 (Figs. 3 and 11) is positioned within the aperture 24 by means of complementary annular shoulders 66 and 68 on the locator member 64 and surrounding the outer end of the aperture 24. The locator member 64 has a through bore 70 which is of equal diameter to and aligned with the first fluid passage 38 of the housing 26, and which completes the fluid passage between the interior of the tool body 12 and the interior of the housing 26. The locator member 64 further includes an annular groove 72 formed below the shoulder 66 to accommodate a third O-ring 74. The first and third O-rings 42 and 74 ensure fluid seals are established between the housing 26, the locator member 64 and the tool body 12. The innermost surface of the locator member is part-cylindrical (concave) to match the cylindrical surface of the bore 13 of the tool body 12.

[0027] In use, the valve assemblies 20 are normally closed. If fluid pressure in the interior bore 13 of the tool 10 is increased beyond a predetermined level, the pressure acting through the fluid passage 70/38 on the convex surface 52 of the piston head 48 will force the piston 28 to move forward against the force of the spring 32, allowing fluid to exit the tool 10 via the apertures 18. In use, the tool 10 would be connected in a drill string (not shown). By controlling the fluid pressure within the drill string, a proportion of the drilling fluid passing downwards through the drill string may thus be diverted outwardly through the apertures 18 in order to assist in the clearance of cuttings and other debris from the annulus around the drill string.

[0028] The fluid pressure required to open the valve assemblies 20 may be adjusted by varying the size of the fluid passage 70/38, and/or the strength of the bias spring, and/or the distance between the shoulder 58 of the piston 28 and the retaining plug 30. The valve assemblies 20 close automatically when the internal fluid pressure is reduced, as the spring 32 urges the convex surface 52 of the piston head 48 back into engagement with the concave surface 36 of the housing 26.

[0029] The angle of the fluid jet exiting the tool can be varied simply by varying the angle of the second fluid passage 44. This can be done by a simple modification of the valve housing without having to modify any other components. The configuration of the valve assembly is such that it can be accommodated in relatively thin tool walls and is thus suitable for use in tools having relatively small outside diameters. The valve assembly is also generally simpler and less expensive to manufacture and maintain than the prior art.

[0030] The tool body 12 would normally be formed of steel. The valve housing 26, piston 28 and locator member 64 are preferably formed of erosion resistant materials. In particular, it is preferred that these components are formed from shatterproof, erosion resistant ceramic material, most preferably non-porous (vacuum tight) alumina, such as type UL 995 T1, from VZS-Seagoe Advanced Ceramics Ltd, Glenrothes, Scotland, United Kingdom. The spring 32 and retaining plug 30 may suitably be formed of steel.

[0031] Besides its intended use as a fluid diverter tool, the invention might also be employed as a pressure relief tool to protect a mud motor located in a drill string downstream of the tool in the event that the motor stalls or the internal fluid pressure increases for other reasons. The tool might further be modified to act as a stabiliser (with or without back-reaming functions) in the manner disclosed in W096/04458.

[0032] Improvements and modifications may be incorporated without departing from the scope of the invention.

Claims

1. A downhole fluid diverter tool comprising: a generally cylindrical body having a longitudinal axis and an axial through-bore and adapted for connection within a drill string, said body having at least one fluid passage extending through a side wall thereof; and at least one normally-closed pressure-actuated valve means associated with said at least one fluid passage whereby a proportion of a flow of drilling fluid passing through the cylindrical body, in use, may be diverted through said at least one fluid passage by increasing the fluid pressure in the interior of the cylindrical body such that said valve means opens and a proportion of the drilling fluid exits from

the cylindrical body through said at least one fluid passage; wherein said valve means includes a piston member housed in said side wall and movable in a direction substantially parallel to said longitudinal axis so as to open and close said fluid passage.

2. A downhole fluid diverter tool as claimed in Claim 1, wherein said piston member is slidably located in a bore which extends substantially parallel to said longitudinal axis, said bore having a concave end surface, said fluid passage intersecting said concave end surface, said piston member having a generally convex complementary end surface adapted to seat against said concave end surface so as to close said fluid passage, and said valve means further including bias means for urging said convex end surface of said piston into engagement with said concave end surface of said bore.

3. A downhole fluid diverter tool as claimed in Claim 2, wherein said fluid passage comprises a first portion connecting said through-bore to the bore of said valve means and a second portion connecting the bore of said valve means to an outlet aperture on the exterior surface of the tool.

4. A downhole fluid diverter tool as claimed in Claim 2 or Claim 3, wherein said valve means comprises a housing adapted to be located in a pocket formed in the exterior surface of the body of the tool, said bore and said fluid passage being formed in said housing.

5. A downhole fluid diverter tool as claimed in Claim 4, wherein said housing and said piston member are formed from erosion resistant material.

6. A downhole fluid diverter tool as claimed in Claim 4 or Claim 5, further including an insert member extending through the wall of the tool body between a bottom surface of the valve pocket and the through-bore of the tool body, and having a through-passage formed therein and aligned with the first portion of said fluid passage.

7. A downhole fluid diverter tool as claimed in Claim 6, wherein said insert member is formed from erosion resistant material.

8. A downhole fluid diverter tool as claimed in Claim 5 or Claim 7, wherein said erosion resistant material is a ceramic material.

9. A downhole fluid diverter tool as claimed in Claim 8, wherein said ceramic material is alumina.

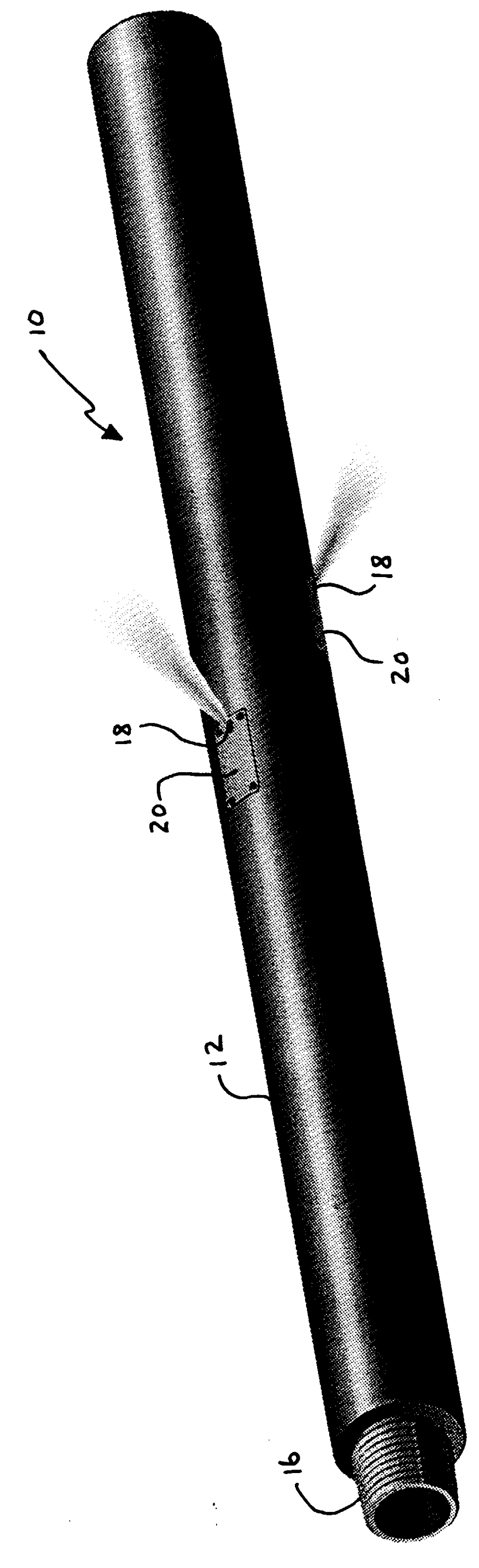


FIG. 1

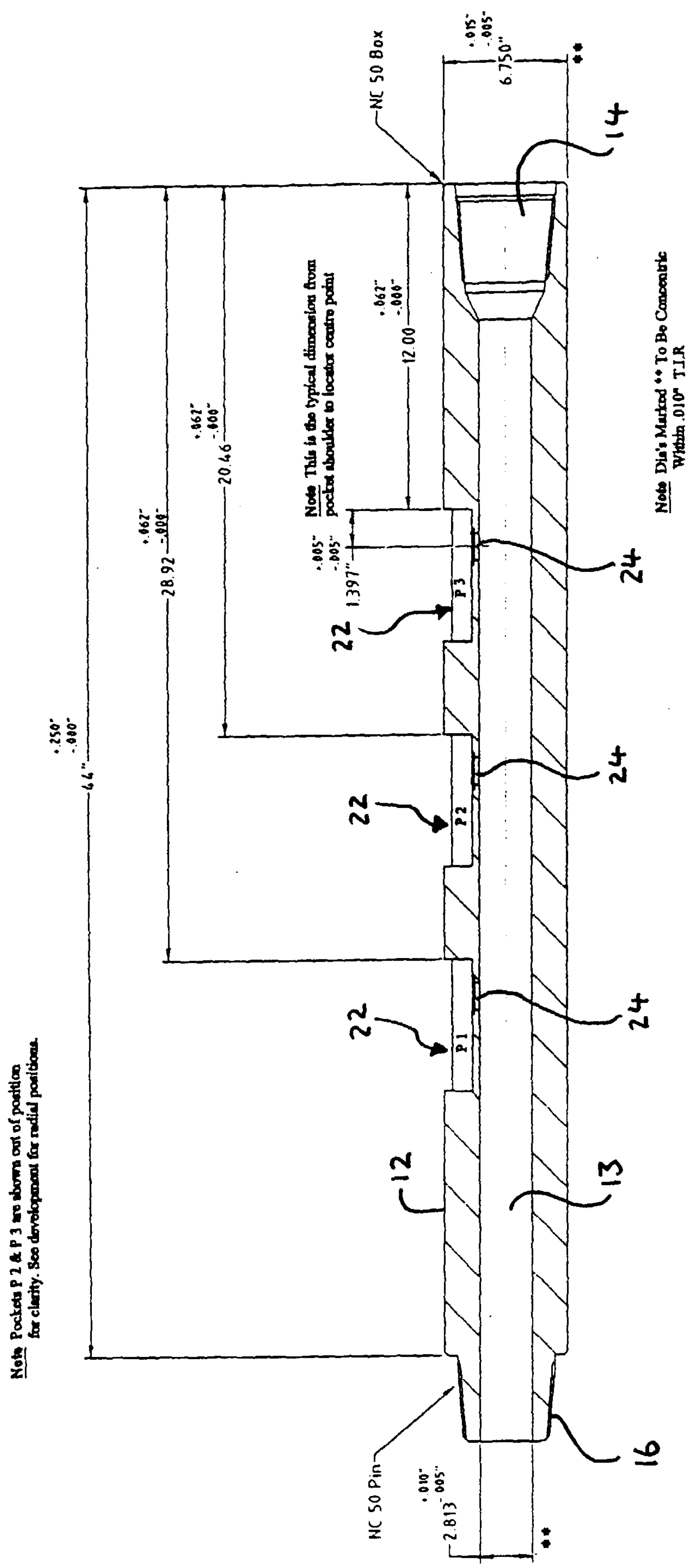

NC 50 Box
6.750"
+.015"
-.005"
14
12.00
+.062"
-.000"
20.46
28.92
44"
+.250"
-.000"
1.397"
+.005"
-.005"
P3
P2
P1
22
24
12
13
16
NC 50 Pin
2.813"
+.010"
-.005"
Note This is the typical dimension from pocket shoulder to locator centre point
Note Dia's Marked ** To Be Concentric Within .010" T.I.R
Note Pockets P 2 & P 3 are shown out of position for clarity. See development for radial positions.

FIG. 2

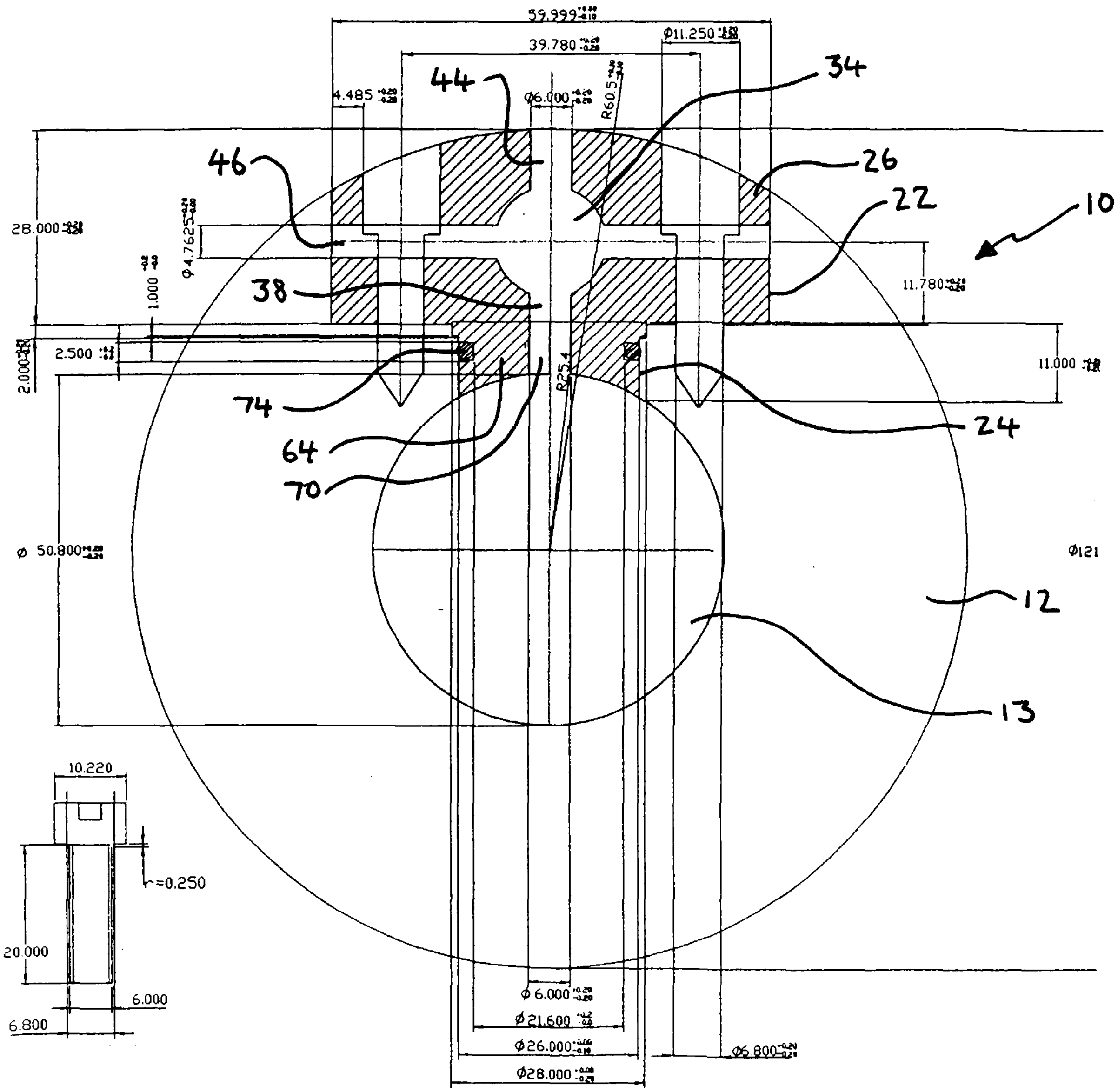

59.999
39.780
Φ11.250
34
44
4.485
Φ6.000
R60.5
46
26
22
10
28.000
Φ4.7625
11.780
1.000
38
2.500
2.000
11.000
74
R25.4
24
64
70
Φ 50.800
Φ121
12
13
10.220
=0.250
20.000
6.000
6.800
Φ 6.000
Φ21.600
Φ26.000
Φ28.000
Φ6.800

Fig. 3

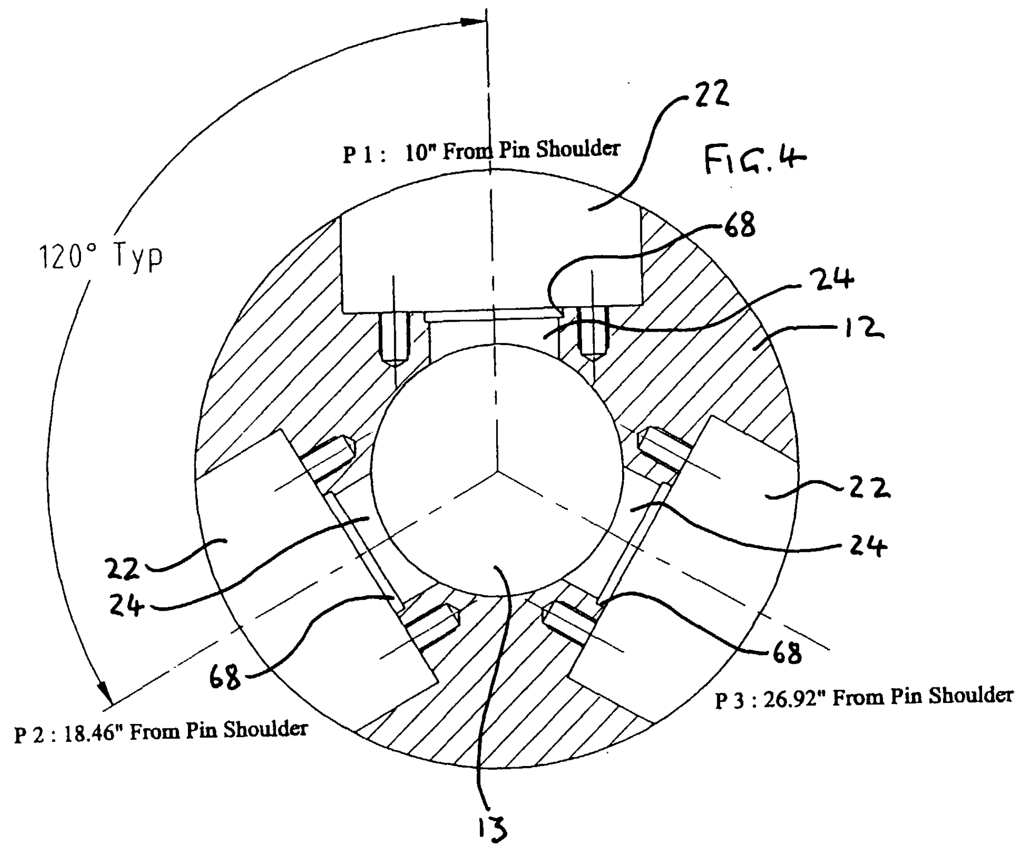


FIG. 4

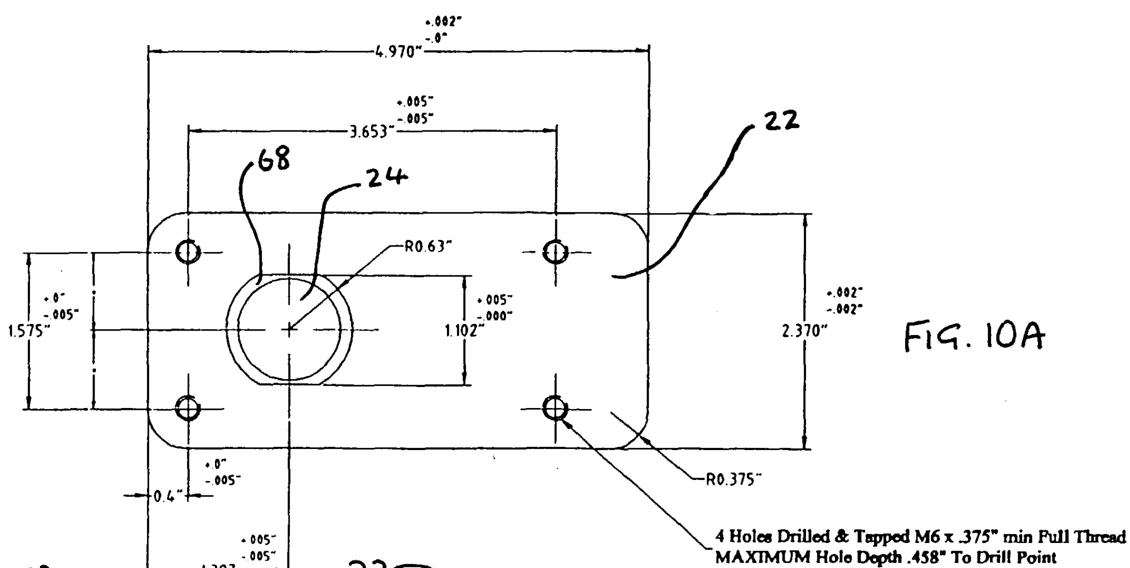


FIG. 10A

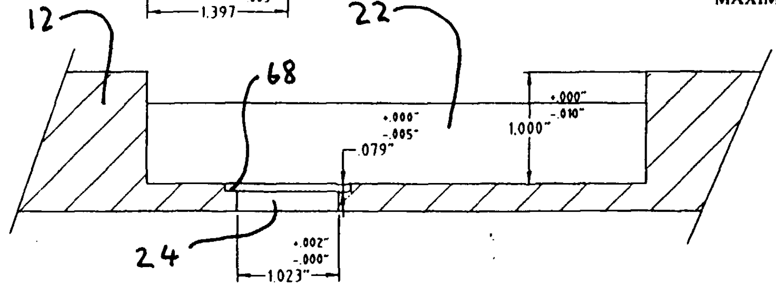
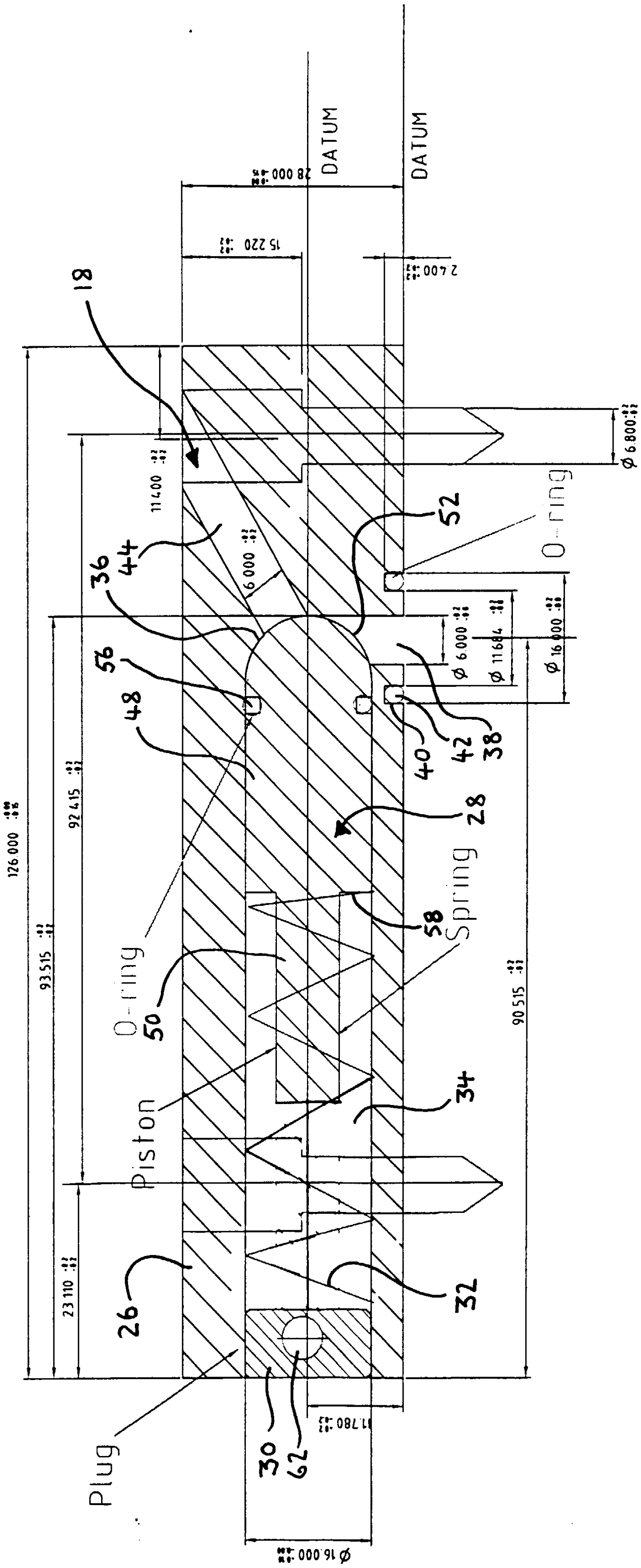


FIG. 10B

FIG. 5


DATUM
DATUM
18
O-ring
52
36
44
56
48
40
42
38
28
Spring
58
O-ring
50
Piston
34
26
32
Plug
30
62

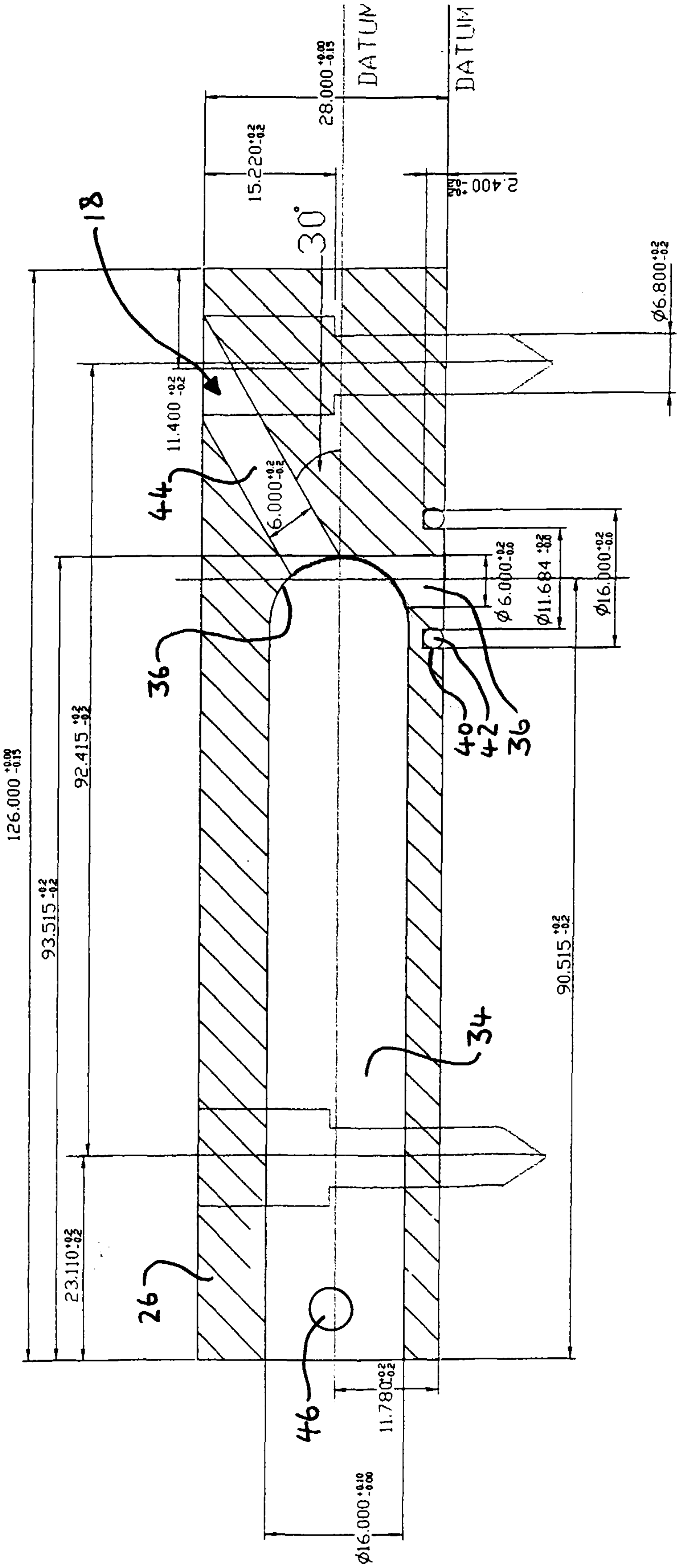


FIG. 6

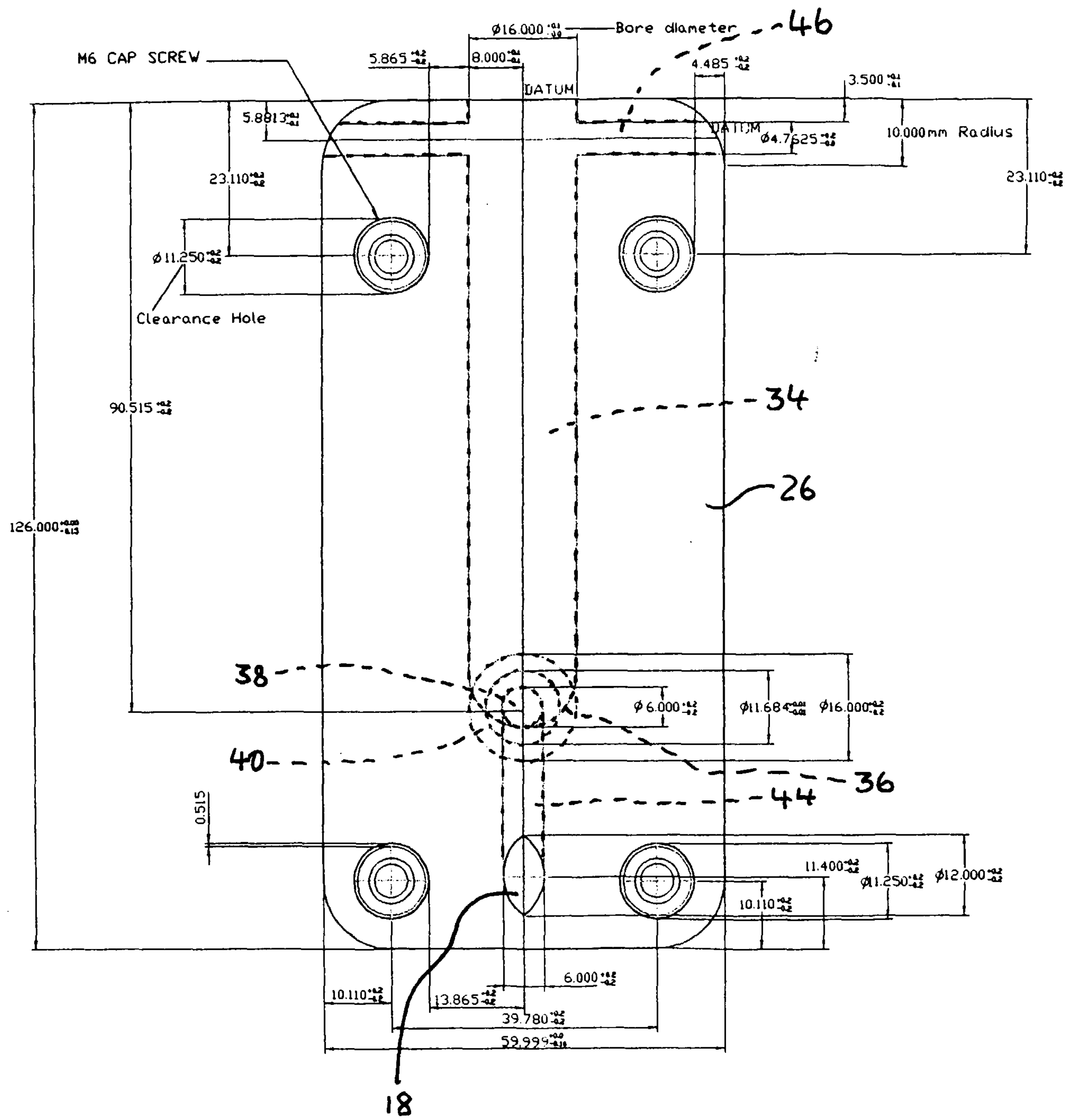

M6 CAP SCREW
Ø16.000
Bore diameter
46
5.865
8.000
DATUM
4.485
3.500
5.8813
DATUM
Ø4.7625
10.000mm Radius
23.110
23.110
Ø11.250
Clearance Hole
90.515
34
26
126.000
38
Ø6.000
Ø11.684
Ø16.000
40
36
44
0.515
11.400
Ø11.250
Ø12.000
10.110
6.000
10.110
13.865
39.780
59.999
18

Fig. 7

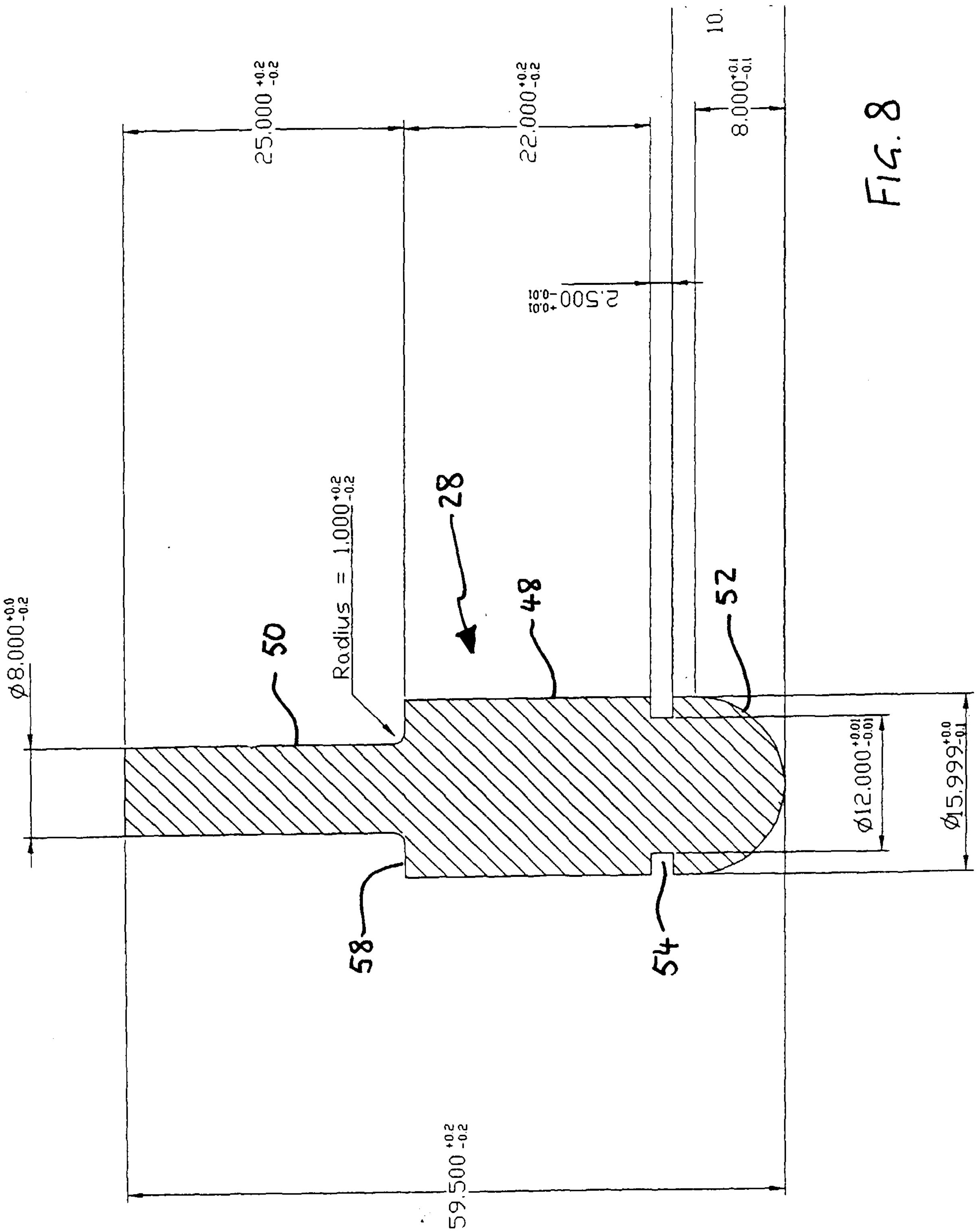
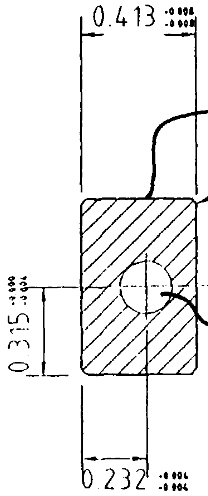

25.000 +0.2 -0.2
22.000 +0.2 -0.2
8.000 +0.1 -0.1
10.
2.500 +0.01 -0.01
Radius = 1.000 +0.2 -0.2
Ø8.000 +0.0 -0.2
Ø12.000 +0.01 -0.01
Ø15.999 +0.0 -0.1
59.500 +0.2 -0.2
28
48
50
52
54
58

FIG. 8

FIG. 9A



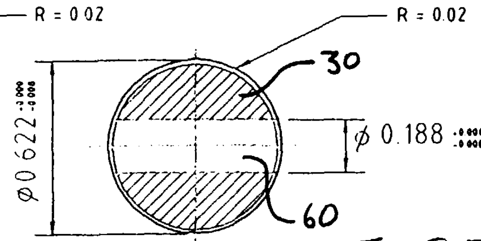
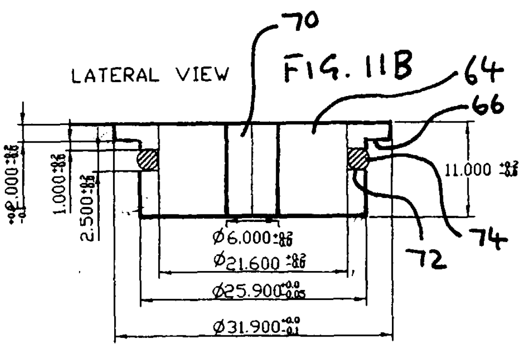
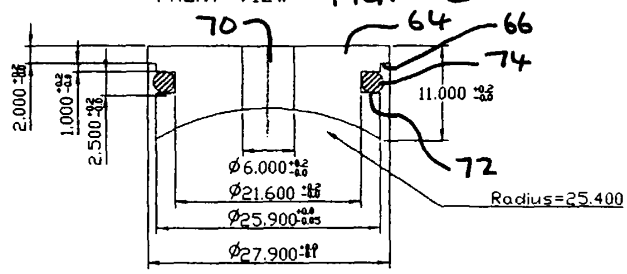


FIG. 9 B

LATERAL VIEW FIG. 11B



FRONT VIEW FIG. 11C



PLAN VIEW

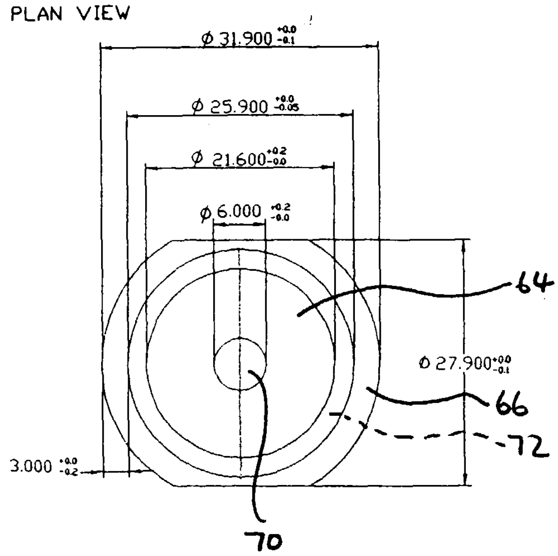


FIG. 11A