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(54) Nozzle attachment for abrasive fluid-jet cutting systems.

(57) The nozzle assembly for use in a fluid-jet cutting apparatus comprises a body (10) having an internal mixing region (20), means (14, 23, 15, 17, 27, 21) for defining a first orifice for directing a high velocity fluid jet along a generally axially extending path and through the mixing region, a conduit (18) in fluid communication with the mixing region (20) and adapted to conduit abrasive into the mixing region - (20) and further comprising a second conduit means in communication with the mixing region (20) for discharging the abrasive-laden jet along a second generally axially extending fluid path. The invention provides for adjustment means (22) for co-axially aligning and/or correcting the alignment of the direction of the high velocity fluid jet (26) with the second discharging conduit means (16).

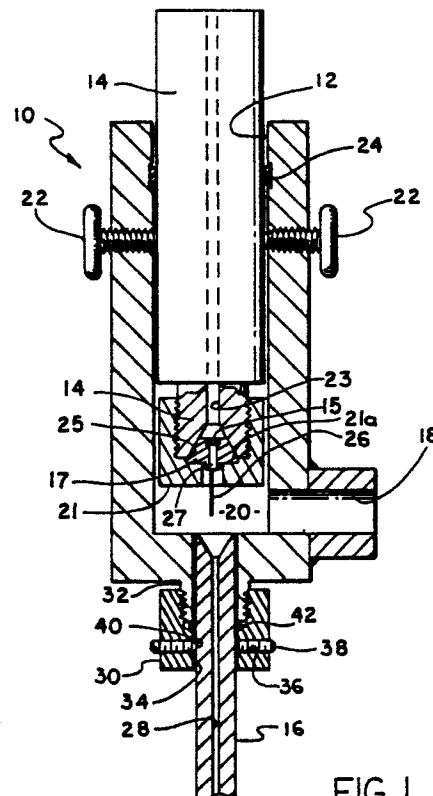


FIG. 1

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NOZZLE ATTACHMENT FOR ABRASIVE FLUID-JET CUTTING SYSTEMS

This invention relates to a method and apparatus for cutting materials by means of a high velocity fluid jet. More specifically, this invention relates to a method and apparatus for producing a fluid jet which contains abrasive particles.

Cutting by means of a high velocity fluid jet is well known in the art. One such system is described in US-A-4 216 906, the contents of which are hereby incorporated by reference. Typically, a fluid, such as water, at pressures up to 3866 kg/cm² (55 000 psi) is forced through an orifice having a diameter of 76 μ m to 760 μ m to generate a jet having a velocity of up to three times the speed of sound. The jet thus produced can be used to cut through a variety of metallic and non-metallic materials such as steel, aluminum, paper, rubber, plastics, Kevlar®, graphite and food products.

To enhance the cutting power of the fluid jet, abrasive materials have been added to the jet stream to produce a so-called "abrasive waterjet". The abrasive waterjet is used to effectively cut a wide variety of materials from exceptionally hard materials such as tool steel, armor plate, aluminum, cast iron, certain ceramics and bullet-proof glass to soft materials such as lead. Typical abrasive materials include garnet, silica and aluminum oxide having grit size of #16 or #400.

The abrasive is typically added to the fluid downstream from the nozzle opening to minimize deterioration of the jet-forming nozzle. In practice, an abrasive waterjet housing containing a mixing region has been mounted on the fluid jet nozzle so that the jet passes through the mixing region and exits from the distal end of the housing. The abrasive waterjet housing is frequently referred to as a "mixing nozzle", and is mounted as an attachment to the fluid jet nozzle. The fluid jet nozzle is also referred to as the "high-pressure" nozzle.

The abrasive is typically supplied from a nearby hopper to the mixing region by means of an abrasive delivery line in fluid communication with the fluid jet via a conduit in the abrasive waterjet housing. The abrasive is drawn from the supply line into the fluid jet by the Venturi effect of the low pressure region surrounding the flowing fluid. In operation, quantities of 0.045 -2.72 kg/min of abrasive material have been found to produce a suitable abrasive waterjet for a wide variety of applications. The abrasive material is accordingly coupled from the hopper to the mixing region through an abrasive-controlling valve which regulates the flow rate of the abrasive material into the jet.

After passing the mixing region, the abrasive waterjet exits from the mixing nozzle through an outlet passageway. To maximize the life of the mixing nozzle, it is highly desirable to align the mixing nozzle and abrasive jet. Unless its internal fluid path is generally concentric with the abrasive jet, the mixing nozzle wears out quickly and becomes inefficient. Additionally, a non-aligned jet has reduced cutting capability because a portion of its energy is dissipated within the mixing nozzle.

Because the fluid path through the abrasive jet housing is several centimeters long, very minute alignment errors (e.g., a few μ m out of perpendicularity) are enough to cause reduced cutting performance and premature failure of the mixing nozzle.

Concentricity and alignment has been difficult to attain for a number of reasons. First, imperfections in the jewels of the high-pressure nozzles cause the path of the fluid jet to deviate from normal by different amounts. Secondly, it is easy to imprecisely install the jewel within the high-pressure nozzle body, causing further deviation of the fluid jet from its theoretical path. Additionally, normal manufacturing tolerances in all components of abrasive jet nozzle can create slight variations in the relationships between the fluid jet path and the path defined by the abrasive jet housing.

In the past, attempts have been made to solve the alignment problem by making the inside diameter of the mixing nozzle very large with respect to the fluid jet diameter, thereby reducing the chance that the jet would impinge on its internal surfaces. Such nozzles have, however, been found to be inefficient in cutting performance.

It is therefore highly desirable that some form of adjustment be provided whereby the fluid jet can be made concentric with the internal fluid path of the mixing tube. Moreover, the adjustment procedure must be sufficiently rapid and simple to permit alignment under practical field conditions, where simplicity and speed are important.

The present invention is directed to a method and apparatus providing such an adjustment. Specifically, a nozzle assembly is described for use in an abrasive-jet cutting apparatus of the type including a source of high-pressure fluid, a high velocity nozzle having an orifice through which said fluid is directed as a high velocity jet, and a conduit for delivering fluid from the source to the nozzle.

The improved nozzle assembly comprises a body having an internal mixing region, first orifice-defining means for directing a high velocity fluid jet along a generally axially-extending path and through the mixing region, conduit means in fluid communication with the mixing region and adapted

to conduct abrasive from a source thereof into the mixing region, second orifice-defining means in fluid communication with the mixing region to receive the abrasive-laden jet from the mixing region and for discharging the abrasive-laden jet along a second generally axial-extending fluid path, and adjustment means for coaxially aligning the first and second orifices.

Because the nozzle assembly can be easily aligned in the field, it may be provided with a disposable insert defining the output passageway for the abrasive jet. Since the output passageway is the component most susceptible to damage, the inclusion of the insert in a rapidly alignable nozzle assembly greatly minimizes "downtime".

Further details concerning the invention will become evident in the following description of the preferred embodiment, of which the following part is a part.

In the drawing

Fig. 1 is a cross-sectional view, in schematic, of an abrasive jet nozzle assembly constructed in accordance with the invention;

Figs. 2 to 4 are sectional views showing alternative embodiments of abrasive jet nozzle assemblies constructed in accordance with the invention.

In Fig. 1, the assembly includes a main body 10 having a generally axially extending throughbore 12. The upper, or proximal, portion of the bore 12 is dimensioned to receive the body 14 of a high-pressure fluid jet nozzle. The lower, or distal, portion of the bore 12 is dimensioned to receive a generally tubular insert 16 formed from hard steel or carbide and of generally annular cross-section.

An abrasive-conducting bore 18 extends generally radially within the main body 10 to couple a source of abrasive (not shown) to a mixing region 20 within the bore 12. The mixing region 20 is located between the distal end of the body nozzle 14 and the proximal end of the insert 16.

The terms "proximal" and "distal" are used throughout this specification to denote the relationship of specified components with respect to the direction of fluid flow; i.e., upstream and downstream, respectively. Additionally, certain components are referred to as being above or below other components when described with respect to the drawing, although those skilled in the art will recognize that the illustrated spatial relationship is not necessary to the practice of the invention.

The nozzle body 14 is held within the main body 10 by a pair of opposing set screws 22 which extend generally radially through the upper portion of the main body 10. The leading ends of the

screws 22 contact the exterior of the nozzle body 14 and, by applying opposing radial forces to the nozzle 14, prevent the body 14 from moving axially or rotationally within the main body 10.

The mixing region 20 is sealed from atmosphere by a pair of axially spaced plastic O-rings 24, 42. The proximally located O-ring 24 fits securely around the nozzle body 14 and is accommodated by a circumferential notch formed in the side wall of bore 12, thereby also restricting movement of the nozzle when the set screws 22 are loosened. The other O-ring 42 fits securely around the insert 42 and is itself secured to the assembly by a nut 30, described below.

The components within the nozzle body 14 include a jewel element 15, such as a sapphire, having a central orifice through which pressurized fluid is forced to form the waterjet. The jewel element 15 is mounted on a holder 17. The holder 17 is retained within the nozzle body by a retainer cap 21 threaded onto the distal end of the nozzle body 14. The pressurized fluid is conducted to the proximal, or upstream, end of the orifice by an internal, generally axially-extending passageway 23 within the nozzle body 14. The passageway 23 terminates at the distal end of the nozzle body, and on the distal side of the jewel element 15, in a counter bore 25 shaped as a conical section.

The jewel holder 17 is formed as a conical section, whose tapered exterior mates with the complimentary taper of the counterbore 25. The holder 17 includes an axially extending passageway 27 in communication with the holder's proximal and distal faces. The proximal end of the holder's passageway is countersunk to hold the jewel element 15 so that the holder's passageway 27 is aligned with the orifice in the jewel.

In operation, the fluid jet 26 emerges from the orifice in the high-pressure nozzle body 14 and travels axially through the mixing region 20 and through the internal passageway 28 of the insert 16. As the fluid jet 26 passes through the mixing region 20, and low pressure region surrounding the flowing fluid causes abrasive particles form passageway 18 to become mixed with the fluid jet, resulting in an abrasive laden jet. Because the mixing region is sealed from atmosphere by the O-rings 24, 42, a relatively high vacuum can be created which is applied essentially only to the abrasive passageway 18.

The abrasive-laden jet, or simply abrasive jet, travels axially through the internal passageway 28 of the insert 16 and is discharged at the distal end of the insert to cut material positioned below the insert.

In practice, carbide inserts approximately 50-100 mm long with a 6.4-12.7 mm outer diameter can be used. In general, the internal diameter of the insert is preferably the sum of twice the diameter of the abrasive particle, plus the outer diameter of the fluid jet. When used in conjunction with a 0.46 mm diameter high-pressure nozzle orifice, an insert having a 1.27-1.52 mm internal diameter has been found optimum together with abrasives of Mesh No. 80-60. When used with a 0.33 mm diameter high-pressure nozzle orifice, a 1.0-1.25 mm internal diameter insert together with Mesh No. 80 to 150 abrasive is preferred.

It is highly desirable that the passageway 28 of the insert 16 be concentric with the waterjet 26 in order to avoid impingement of the jet against the inner wall of the insert 16. There are, however, a number of sources of alignment error. For example, non-concentricity of the mating tapered surfaces of the holder 17 and the nozzle body counterbore can result in alignment errors. Imperfections in the inside face 21a of the alignment cap 21 can cause misaligned seating of the holder 17. Additionally, the jewel holder, or the jewel itself, can be assembled imprecisely, particularly where field replacement is necessary.

The illustrated assembly accordingly provides for adjustment of the insert's passageway 28 for co-axial alignment with the fluid jet 26. An alignment nut 30 is accordingly tightened onto a downwardly extending, generally cylindrical, externally threaded neck 32 of the main body 10. The nut 30 includes a throughbore 34, the top portion of which is dimensioned to circumscribe the neck 32. The lower portion of the bore 34 is dimensioned to circumvent the insert 16.

The nut 30 includes three internally threaded, generally radially extending bores 36 through which respective screws 38 extend. The leading ends 40 of the screws 38 contact the outer surface of the insert 16. The screws 38 are preferably spaced symmetrically about the circumference of the nut 30. The bore 34 is slightly oversized with respect to the outer diameter of the sleeve so that, by selectively advancing or withdrawing each of the leading screw ends 40, the lateral and angular positions of the insert 16 within the bore 34 can be adjustably varied. The alignment assembly further includes means such as O-ring 42 for retaining the insert within the bore during adjustment of the set screws. The O-ring 42 is compressed between the face of the neck 32 and the internal shoulder of the nut. The O-ring 42 fits tightly about the insert to provide frictionally-generated resistance against axial movement against the insert prior to the tight-

ening of the set screws. The O-ring 42 is formed from resiliently compressible material to accommodate lateral movement by the insert in response to adjustment of the screws.

Figure 2 is a cross-sectional view in schematic of an alternative embodiment of the invention, wherein components similar to those illustrated in Figure 1 have been designated with corresponding numerals. In the embodiment of Figure 2, the high-pressure nozzle body 14' includes a region of reduced outer diameter 42' adapted for a contact by the leading edge of the fastening screws 22' when the nozzle body 14' is within the main body 10.

The waterjet-producing orifice within the high-pressure nozzle body 14' is angularly adjustable about a pivot point, preferably located at the center of the orifice. Accordingly, the insert and mixing region may be relatively rotated into correct alignment with the orifice of the high-pressure nozzle body.

Accordingly, the distal face of the high-pressure nozzle body 14' is provided with a generally spherical shape whose radius of curvature is centered on the upstream face of the orifice-defining jewel. The distal face of the nozzle serves as a "ball of a ball-and-socket-like" linkage arrangement.

The main body 10 includes a guide surface adapted to interface with the spherical surface.

Figure 3 is a sectional view in schematic of a third alternative embodiment of the invention, which includes upper and lower body members 100, 102. The upper body member 100 includes a peripheral flange-like portion 118 having a plurality of circumferentially-spaced through-holes 120 communicating with the proximal and distal faces 104, 106, respectively, of the peripheral portion 118.

The proximal face 104 of the upper body member has a generally cylindrical hub 108 which extends axially in the proximal direction, and through which a bore 110 is formed. The bore 110 is internally threaded at its upper portion 112. An orifice 114 is defined by means such as a jewel element 116 positioned within the bore 110 approximately midway along the bore.

The axially distal face 122 of the upper member 100 is generally spherical in shape, having a curvature whose center of rotation is located at the center of the orifice 114.

The bore 110 forms a fluid passageway which is coupled at its proximal end 112 to a source of high-pressure fluid. As the fluid passes through the orifice 114, it forms a high-velocity fluid-jet.

The lower body member 102 includes a generally central, axially-extending throughbore 124. The throughbore 124 comprises a proximal zone 126 of relatively large diameter, a mid-zone 128 of

a relatively small diameter, and a distal zone 140 of intermediate diameter. A spherically concave shoulder 132 defines the transition between the proximal zone 126 and the mid-zone 128.

The lower, or distal, portion 130 of the through-bore 112 is dimensioned to accept a carbide insert 134. The region 130 may be internally threaded to engage external threads formed on the insert 134. Alternatively, an alignment mechanism such as collar 30 (Figure 1) may be utilized.

The upper member 100 is assembled onto the lower member 102 so that the distal portion of the central hub member 108 fits within the lower member 102. The lower member 102 includes an outer flange-like periphery 136 at its proximal end. Internally threaded through-holes 138 are circumferentially disposed within the flange-like region 136 so as to underlie the holes 120 in the upper member 100 when the members 100, 102 are assembled.

Adjusting screws 140 are inserted through the holes 120 and are threaded into the holes 138.

The flange-like periphery 136 of the upper member 100 is positioned so that it is axially spaced from the flange-like periphery of the lower member 102 when the distal face 122 of the upper member 100 contacts the guiding surface 132 of the lower member 102. The spacing between the opposing flange-like peripheries 104, 136 can be adjusted by selectively tightening or loosening each of the peripherally disposed screws 140.

Referring to Figure 3, it will be clear that the tightening of the left screw 140 will cause a decrease in spacing between the two flanges at the left and a consequential counterclockwise rotation of the upper member 100. As the upper member 100 rotates counterclockwise, it pivots on its distal face 122 causing the orifice 114 to move with respect to the inner passageway of the insert 134. By selectively tightening and loosening the set screws 140, the orifice 114 can be aligned with the passageway through the bore.

It is advantageous to provide both a lateral adjustment, such as that illustrated in Figure 1, together with a rotational adjustment such as that illustrated in Figure 3 so that the axis 150 of insert 134 can be made concentric with the axis through the orifice 114.

Figure 4 shows another embodiment of the invention. For brevity, only the difference in alignment features will be discussed. The alternative mixing nozzle 100 comprises an upper body member in the form of a cap 102 and a lower body member 104. The cap 102 includes an upper large diameter portion having a multi-sided periphery for enhanced gripability, and a lower smaller diameter portion 108. The top region of the lower portion 108 is externally threaded at 110, while the lower region of the lower portion has an arcuate surface

109 adapted to form the ball in a ball-and-socket arrangement. The arcuate surface 109 has a center of rotation generally co-existent with the high-pressure nozzle opening (not shown).

The bottom portion of the attachment 110 includes a generally annular nut-like member 112 conveniently provided with the same diameter as the top portion of the cap. The nut-like member 112 is internally threaded in its upper region 113 to engage the external threads on the cap. The lower region 114 of the nut-like member 112 is provided with an interior wall of converging shape which extends downward from the bottom of the threaded region of its distal face.

The proximal face 104a of the lower body member 104 includes a socket-defining central region formed within a converging, downwardly extending interior wall 105. The exterior wall 106 circumventing the central region is similarly shaped and of larger diameter than the internal diameter of the nut-like member at the member's distal face. The lower body member 104 is accordingly retained within, but freely movable within, the nut-like member so that it can be angularly pivoted from the vertical in all directions with the inner wall 105 of the lower body member 104 engaging the arcuate surface 109 of the upper body member or cap 102.

Accordingly, the passageway 120 in the lower body member portion may be angularly pivoted with respect to the axis 125 through the passageway 124 in the cap 102 until the abrasive jet passageway is aligned with the fluid jet. The cap 102 is then tightened into the nut-like member 112 so that its arcuate surface presses both axially and radially against the inner wall 105 of the lower body member preventing relative pivoting of the two body members.

Claims

1. For use in a fluid jet cutting apparatus of the type including a source of high pressure fluid, a high velocity nozzle having a nozzle opening (15) through which said fluid is directed as a high velocity fluid cutting jet (26), and a conduit (23) for delivering fluid from said source to the nozzle opening, an improved nozzle assembly for producing an abrasive jet being characterized by: a body having an internal mixing region (20); orifice-defining means (14, 17, 25, 21) for directing a high velocity fluid jet (26) along a generally axially-extending path and through the mixing region (20); first conduit means (18) in fluid communication with the mixing region (20) and adapted to conduct abrasive from a source thereof into the mixing region (20);

second conduit means (16, 28) in fluid communication with the mixing region (20) to receive the abrasive-laden jet from the mixing region (20) and for discharging the abrasive-laden jet along a second generally axial-extending fluid path; and adjustment means (22; 102, 112) for co-axially aligning the orifice and second conduit means (16; 134).

2. The nozzle of Claim 1 including a first nozzle body (14) circumscribing the orifice-defining means,

a second nozzle body (10) circumscribing the second conduit means, and

means for coupling the first and second nozzle bodies for relative movement to co-axially align the orifice with the second conduit means (16; 134).

3. The nozzle of Claim 2 wherein one of the two nozzle bodies is dimensioned so that at least a portion of it fits within at least a portion of the other, and the coupling means includes means for adjusting the lateral position of said one of the bodies with respect to said other of the bodies.

4. The nozzle of Claim 3 wherein the adjusting means includes a circumferentially spaced plurality of adjusting screw means (22) for applying a laterally directed positioning force.

5. The nozzle of Claim 4 wherein the adjusting screw means includes a plurality of adjusting screws extending inwardly through the outer nozzle body (10) to apply an inwardly directed positioning force against the inner nozzle body.

6. The nozzle of Claim 1, Claim 2 or Claim 5 including a ball-and-socket type linkage means - (122, 132) for permitting the pivoting of the orifice about the second conduit means.

7. The nozzle of Claim 3 including ball-and-socket linkage means for permitting the pivoting of the orifice about the second conduit means.

8. The nozzle of Claim 7 wherein the inserted end portion of said one nozzle body includes a generally convex guide surface (122) adapted to function as the ball of a ball-and-socket type linkage arrangement.

9. The nozzle of Claim 8 wherein said other of the nozzle bodies includes a second guide surface (132) adapted to function as the socket of a ball-and-socket type linkage arrangement, and positioned to cooperate with the generally convex guide surface to for the ball-and-socket type linkage.

10. The nozzle of Claim 8 wherein the generally convex guide surface has a focus at the center of the fluid jet orifice.

11. For use in a fluid jet cutting system, a nozzle assembly being characterized by:
orifice defining means adapted for fluid communication with a source of high-pressure fluid;
conduit means in fluid communication with the first orifice-defining means and adapted for fluid communication with a source of abrasive;
a first flanged body (100) containing the orifice-defining means;
a second flanged body (102) containing the conduit means; means for coupling the flanges of the first and second flanged bodies at adjustably spaced relationship to align the orifice and conduit means.

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FIG. 1

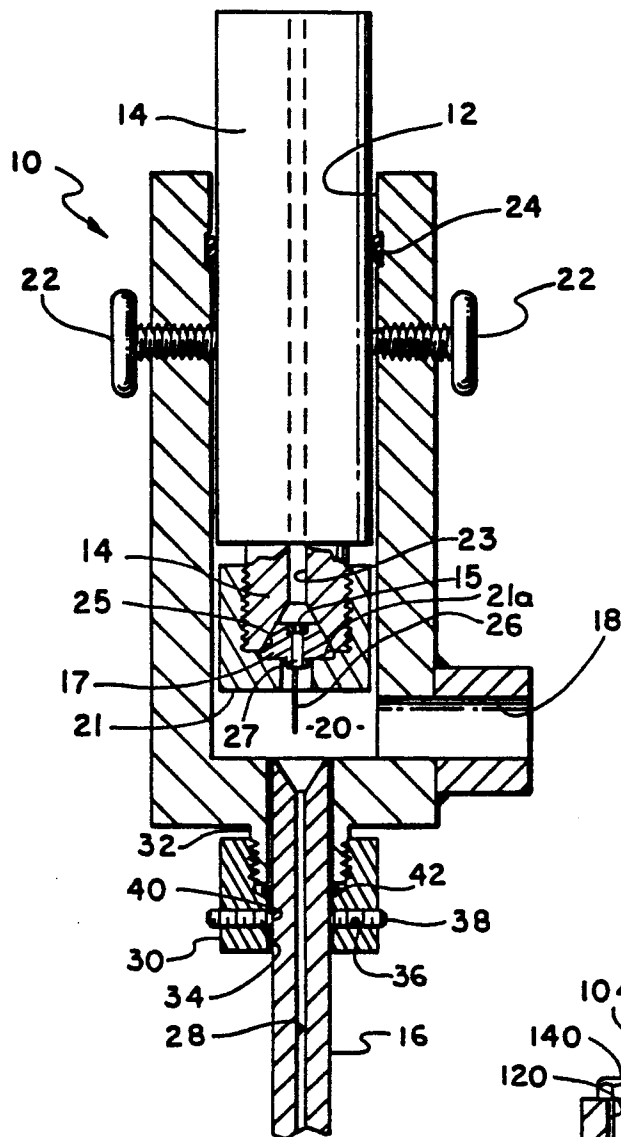
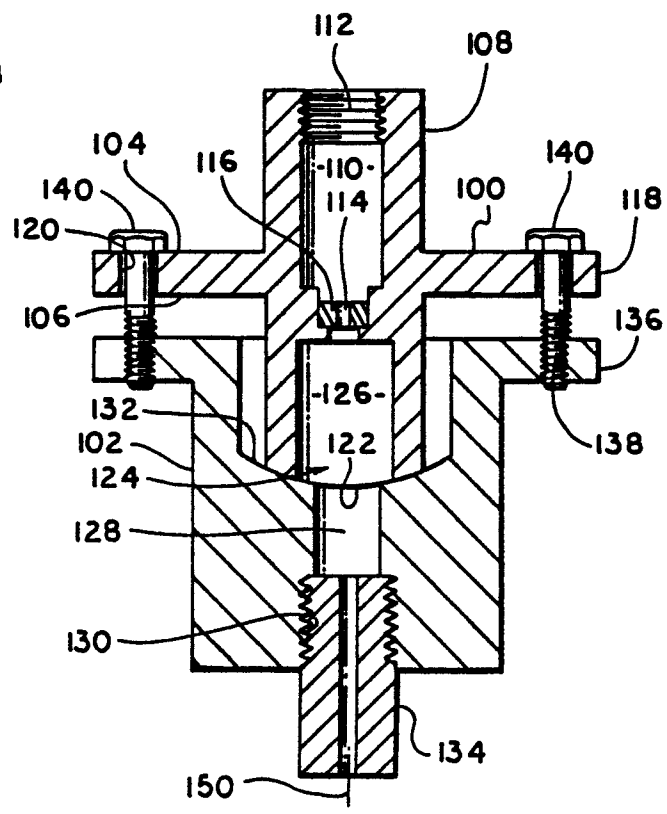


FIG. 3



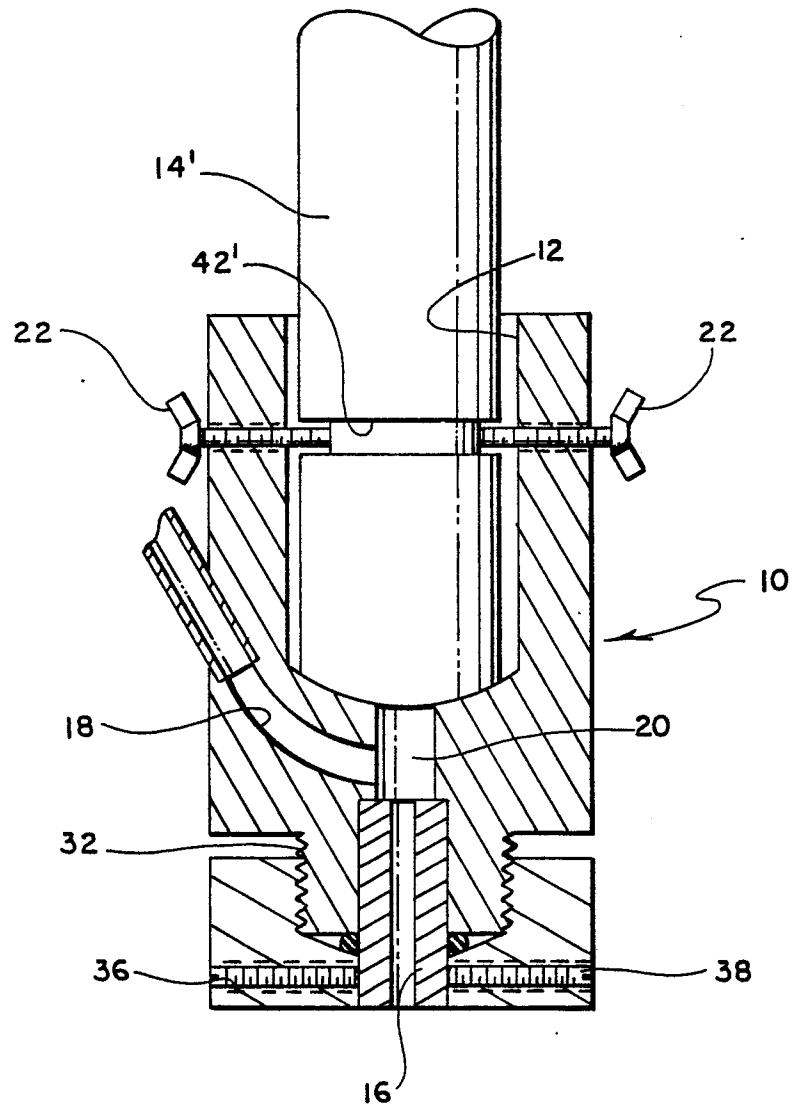


FIG. 2

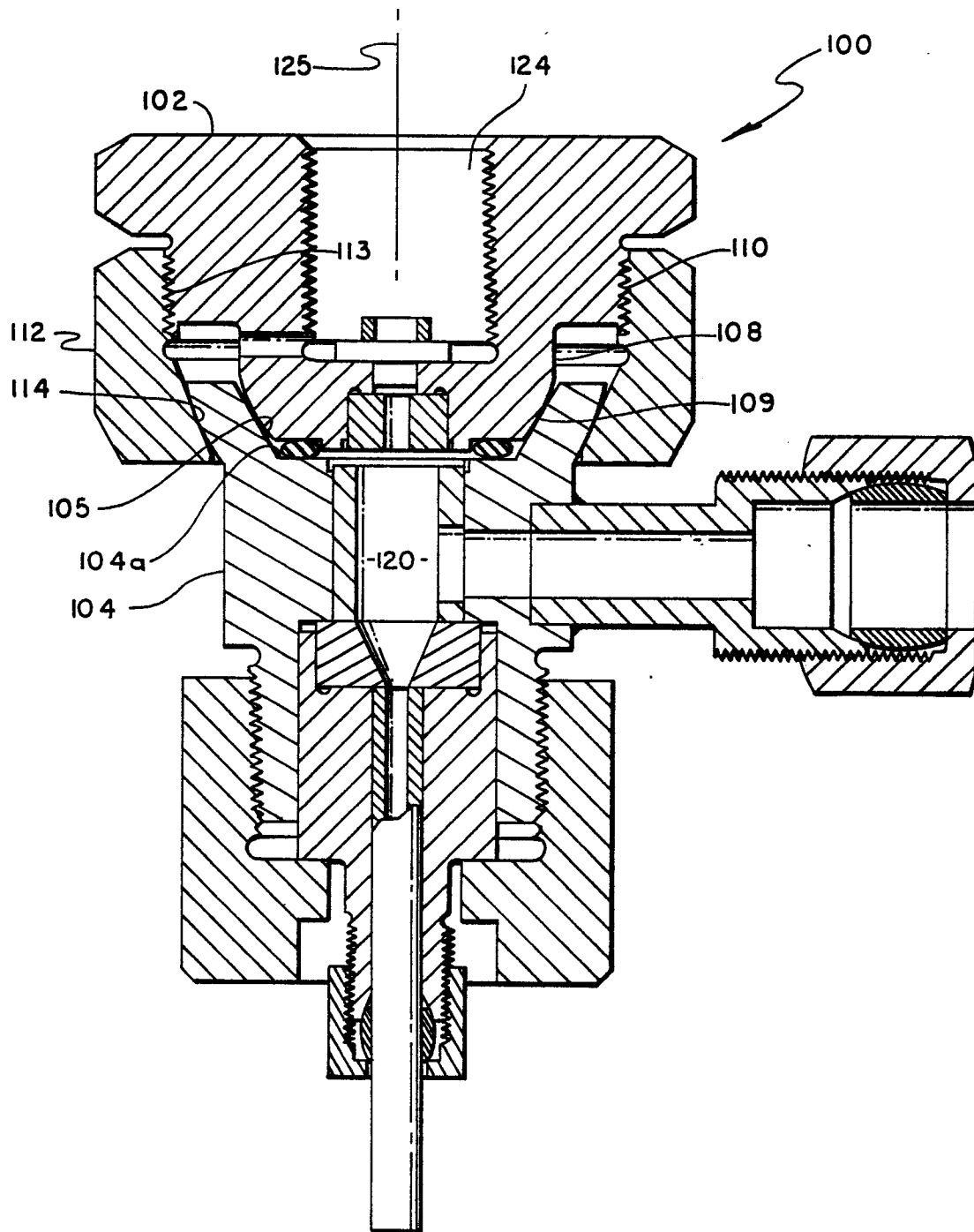


FIG. 4



DOCUMENTS CONSIDERED TO BE RELEVANT			EP 86108664.3
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
P, A	<u>FR - A1 - 2 570 638 (LIBBEY)</u> * Fig. 2 * --		B 26 F 3/00
A	<u>DE - A1 - 3 043 777 (FLOW)</u> * Fig. 1 * ----		
			TECHNICAL FIELDS SEARCHED (Int. Cl.4)
			B 26 F
The present search report has been drawn up for all claims			
Place of search VIENNA		Date of completion of the search 23-12-1986	Examiner HOFMANN
CATEGORY OF CITED DOCUMENTS			
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	