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(81) Designated States (unless otherwise indicated, for every
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BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM,
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KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD,
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(54) Title: **PRESSURE CARTRIDGE**

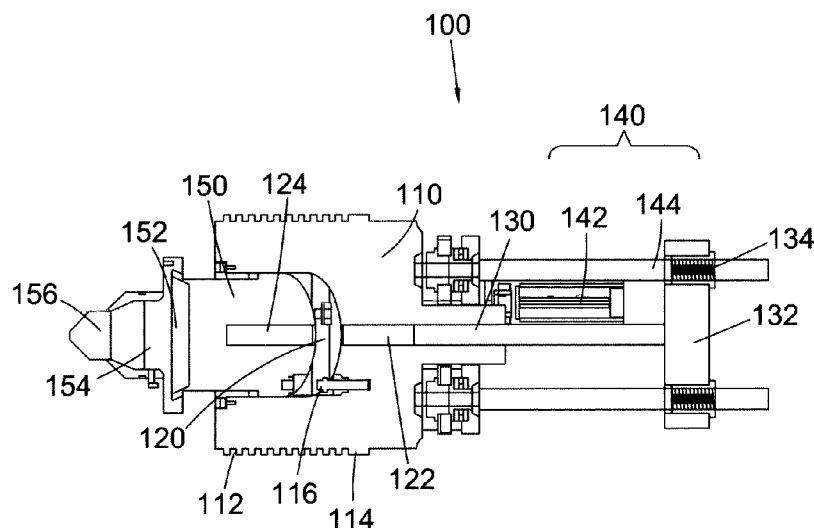


Fig. 1B

(57) Abstract: A cartridge assembly comprising a chamber for containing hydraulic fluid, an intensifier element capable of reciprocating in the chamber and displacing the hydraulic fluid responsive to a drive means acting on the intensifier element, and a piston capable of reciprocating in the chamber and being displaceable responsive to a change in the pressure of the hydraulic fluid. The cartridge assembly is configured so that when the pressure in the fluid increases responsive to a first force being applied by the drive means on the intensifier, the hydraulic fluid will exert a second force on the piston, the second force being greater than the first force; the mass of the hydraulic fluid being substantially conserved within the cartridge assembly.



**Declarations under Rule 4.17:**

- *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*
- *of inventorship (Rule 4.17(iv))*

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PRESSURE CARTRIDGE

This disclosure relates generally to a cartridge assembly for generating pressure, particularly but not exclusively for an ultra-high pressure press.

5

United States patent number 6,336,802 discloses a unitary press frame and unitary cartridge with internal intensification. The cartridge body comprises a first chamber, a second high-chamber, and a connecting cylindrical passageway. Installed inside the first high chamber of the cartridge body are a plug and the internal fluid intensifier piston, the plunger of which is inserted into the cylindrical passageway. In normal operation of the press cycle, the pressurized fluid from an external pumping source is admitted into the first chamber via an inlet, forcing the internal fluid intensifier piston forward. The forward motion of the piston acts upon the fluid in the second high-chamber and urges the anvil/piston forward. As the anvil/piston comes in contact with a typical reaction cell, the fluid pressure from the external pumping source is increased in the first chamber causing amplified fluid pressure to build in the second chamber, behind the anvil/piston. The anvil/piston then acts as a mechanical intensifier of the pressurized fluid working on it, generating ultra high pressure at the anvil face.

20 There is a need for a more compact ultra-high pressure generation cartridge, preferably having reduced risk of hydraulic fluid losses. As used herein, an ultra-high pressure is at least about 1 GPa.

Viewed from a first aspect there is provided a cartridge assembly (for generating pressure), particularly but not exclusively for generating ultra-high pressure, comprising a chamber for containing hydraulic fluid, an intensifier element capable of reciprocating in the chamber and displacing the hydraulic fluid responsive to a drive means acting on the intensifier element, and a piston capable of reciprocating in the chamber and being displaceable responsive to a change in the pressure of the hydraulic fluid; the cartridge assembly configured so that when the pressure in the fluid increases responsive to a first force being applied by the drive means on the intensifier, the hydraulic fluid will exert a second force on the piston, the second force being greater than the first force; the hydraulic fluid being substantially conserved within the cartridge assembly (substantially no hydraulic fluid entering or leaving the cartridge assembly). The ratio of the second force to the first force will depend on the configuration of the piston and

intensifier rod within the chamber according to known hydro-mechanical (hydraulic) principles.

Various arrangements and combinations are envisaged for cartridge assemblies by this disclosure, of which the following are non-limiting, non-exhaustive examples.

The cartridge assembly may comprise a housing. The cartridge assembly may comprise a chamber for containing hydraulic fluid, an intensifier rod capable of reciprocating in the chamber, a piston and an electro-mechanical drive means for driving the intensifier rod into the chamber and withdrawing it from the chamber.

The intensifier element may be attached at a proximate end to a ram external to the chamber, the ram being coupled to the drive means.

The drive means may comprise a servomotor coupled to a threaded beam having a longitudinal axis, the position of which is substantially fixed relative to the housing; the servomotor and the beam arranged such that rotation of the beam about its longitudinal axis can be selectively driven by the servomotor; the intensifier element being driveably coupled to the threaded beam by means of a cooperatively threaded mechanism, such that rotation of the beam will result in a longitudinal force being applied to the intensifier element via the threaded mechanism.

The intensifier element may be an elongate member such as a rod, which may be cylindrical in shape. The intensifier element may be attached to a ram at the proximate end, the ram being coupled to the drive means, which may comprise an electro-mechanical device. In some example arrangements, the drive means may comprise a servomotor such as a stepper motor. The servomotor may be coupled to a threaded beam, or to at least a pair of threaded beams, the position of which is fixed relative to the housing of the cartridge assembly. The servomotor and the beam may be arranged such that rotation of the beam about its longitudinal axis can be selectively driven by the servomotor. The servomotor and the beam may be attached to the housing. The ram may be coupled to the beam by means of a cooperatively threaded mechanism, such that rotation of the beam will result in a longitudinal force being applied to the ram via the threaded mechanism. The ram may thus be displaced in either direction along the longitudinal axis responsive to rotation of the beam. In other

words, driven rotation of the beam or beams can be converted into longitudinal force on the ram, which may result in longitudinal displacement of the ram provided its longitudinal displacement is not prevented. Longitudinal displacement of the ram will result in longitudinal displacement of the intensifier element, resulting in longitudinal displacement of the distal end of the intensifier element located within the chamber. The first force may thus be applied to the intensifier element by the action of the servomotor. The drive means may comprise at least two or three threaded beams to which the ram will be coupled, which is likely to result in the drive means being more efficient and stable.

The housing may comprise a guide bore for the intensifier element, the guide bore connecting the chamber with the outside of the housing; the intensifier element located in the guide bore arranged with a proximate end located outside the housing and a distal end located within the housing; the cartridge assembly comprising a seal means arranged with respect to the housing and the intensifier element such that hydraulic fluid is substantially prevented from escaping from the chamber while the intensifier element is capable of reciprocating in the guide bore.

The piston may have a proximate end located inside the chamber, the proximate end of the piston abutting a seat defined by an inner surface of the chamber when the piston is fully inserted into the housing.

The piston may have a proximate end located inside the chamber and an opposite distal end, the piston comprising a receiver bore in the proximate end for accommodating part of the intensifier element adjacent the distal end of the intensifier element.

The housing may comprise a guide bore for the intensifier element and the piston comprises a receiver bore in the proximate end of the piston for accommodating part of the intensifier element adjacent the distal end of the intensifier element, the guide bore and the receiver bores being substantially aligned such that the intensifier element can extend from the guide bore and into the receiver bore.

The receiver bore and guide bore may be in communication with each other and substantially all hydraulic fluid in the chamber may be contained in a volume defined by the guide bore and the receiver bore when the piston is fully inserted into the chamber.

An anvil for impinging a body to be pressurised may be mounted onto the distal end of the piston. The anvil may be mounted onto an anvil holder, which may be mounted onto a position adjustment mechanism for adjusting the position of the anvil in the lateral plane, which may be mounted onto the distal end of the piston.

The housing may be configured for insertion into and coupling to a bore provided in a frame, for example a frame for a press apparatus such as an ultra-high pressure press apparatus, as may be used for the synthesis and or sintering of super-hard material such as diamond or cubic boron nitride (cBN) material.

Viewed from a second aspect there is provided a press system comprising a press frame and a cartridge assembly according to this disclosure.

The press system may be a cubic, tetrahedral or uni-axial press system, comprising six, four or two cartridge assemblies, respectively.

Certain disclosed cartridge assemblies may have the aspect of enhanced space that less space is required for housing the assembly. In addition, less high pressure tubing, fewer seals and sealing surface are likely to be required since there is no need to pump hydraulic fluid into and out of the cartridge assembly. The cartridge assembly may have reduced mass, and is likely to be easier to maintain.

Non-limiting example arrangements will be described with reference to the accompanying drawings, of which

Fig. 1A shows a schematic cross section view of an example cartridge assembly in a fully withdrawn condition;

Fig. 1B shows a schematic cross section view of an example cartridge assembly in a fully extended condition;

Fig. 1C shows a schematic perspective view of an example cartridge assembly;

Fig. 2A shows a schematic side view of an example cubic press system, in which the cartridge assemblies are withdrawn from press frame;

Fig. 2B shows a schematic side view of the example assembly of Fig. 2A, in which the cartridge assemblies are installed in the press frame;

Fig. 2C shows a schematic cross section through the example press frame and one cartridge assembly of the cubic press system of Fig. 2A;

Fig. 2D shows a schematic cross section through the example press frame and one cartridge assembly of the cubic press system of Fig. 2A; and

5 Fig. 2E shows an isometric perspective view of the cubic press frame of Fig. 2A.

With reference to Fig. 1A to Fig. 1C, an example arrangement of a cartridge assembly 100 for an ultra-high pressure press comprises a housing 110, a chamber 120 for containing hydraulic fluid, an intensifier rod 130 capable of reciprocating in the chamber
10 120, a piston 150 and an electro-mechanical drive means 140 for driving the intensifier rod 130 into the chamber 120 and withdrawing it from the chamber 120. As used herein, hydraulic fluid is a fluid medium by which power can be transferred in hydraulic machinery. Examples of hydraulic fluids include fluids based on mineral oil or water. The housing 110 comprises a guide bore 122 for the intensifier rod 130, the guide bore
15 122 connecting the chamber 120 and the outside of the housing 110. The intensifier rod 130 is located in the guide bore 122 and can reciprocate in it. A seal means is provided between the intensifier rod 130 and the guide bore 122 such that hydraulic fluid in the chamber 120 cannot escape from the chamber to the outside of the housing 110 when the intensifier rod 130 reciprocates in the guide bore 122 as in use. The
20 piston 150 has a proximate end located within the chamber 120 and an opposite distal end located outside the chamber 120. A receiver bore 124 is provided into the proximate end of the piston 150 for accommodating the end of the intensifier rod 130 that can extend from the guide bore 122 and into the receiver bore 124. The receiver bore 124 is aligned with the guide bore 122 and when the piston 150 is fully inserted
25 into the chamber 120 as illustrated in Fig. 1A, the receiver bore 124 is in direct communication with the guide bore 122 and thus in combination the receiver bore 124 and the guide bore 122 substantially define the entire volume of the chamber 120 available for containing hydraulic fluid. When the piston 150 is even slightly extended from the chamber as illustrated in Fig. 1B, a further volume opens up between the
30 chamber wall and the proximate end of the piston 150. The chamber 120 can therefore comprise at least part of the guide bore 122, the receiver bore 124 and a volume between a wall of the chamber and the piston 150.

The rod 130 and piston 150 have respective areas A_1 and A_2 perpendicular to their
35 respective axes of reciprocation (the same axis, in this example) and exposed to the

hydraulic fluid in the chamber 120. The drive means 140 comprises a servo-motor 142 and at least two threaded beams 144 coupled to the servo-motor 142 such that they can be synchronously driven by the servo-motor 142 to rotate about their respective axes. The rod 130 is moveably coupled to each of the threaded beams 144 by means of a ram 132 comprising respective internally threaded coupling screws 134, the thread of the coupling screws 134 and the beams 144 being cooperatively configured such that when the beams 144 rotate, the coupling screws 134 are urged to move along the beams 144 in a direction determined by the direction of rotation of the beams 144 (i.e. either towards the housing 110 or away from it). Consequently, the ram 132 will be driven towards the housing 110 or away from it and the rod 130 will be driven into the chamber 120 or withdrawn from it.

When the rod 130 is driven a distance into the chamber 120, it will tend to compress hydraulic fluid in the chamber 120 with a force F_1 applied by the drive mechanism 140 and to generate a pressure P in the hydraulic fluid. The piston 150 will experience a force of $(A_2/A_1) \times F_1$ in the direction and be urged forward, according to the principles of hydraulic mechanics.

An anvil 156 may be mounted onto the forward end of the piston 150. The anvil 156 may comprise cemented tungsten carbide and be suitable for impinging a capsule for diamond synthesis or sintering. The foremost end surface of the anvil 156 for impinging the capsule may have an area A_3 . The pressure that the anvil is capable of generating on the capsule will be about $(A_2/A_1) \times F_1 / A_3$. The anvil may be mounted on an anvil holder 154, which may be mounted onto an X-Y lateral position displacement stage for adjusting the lateral position of the anvil 156 in a plane perpendicular to the axis L and or rotationally about the axis L .

The housing 110 may comprise ridges, fins, projections or lobes 112 arranged on a circumferential side surface for securing it within a bore hole of a press (not shown) against longitudinal displacement along the axis L with respect to the bore hole, which will comprise cooperatively configured structures for the coupling. The housing may comprise lobes 114 for securing it against lateral (radial) displacement within the bore hole.

With reference to Fig. 2A to Fig. 2E, an example cubic press system 300 comprises a unitary steel frame 500 having six sides, each side provided with a bore hole 510 for accommodating a respective hydraulic cartridge 400. The press frame 500 has a substantially spherical central chamber 550 for housing a capsule to be pressurised.

5 Each cartridge 400 is mechanically fastened to the press frame 500 by respective axial and radial fastening mechanisms. Each cartridge 400 comprises a generally cylindrical body 410 provided with components a radial fastening mechanism 412 and axial fastening mechanism 415. The corresponding bore hole 510 is also provided with complementary components for the radial and axial 515 fastening mechanisms. The
10 axial fastening mechanism involves a plurality of ribs 415 on the body 410 of the cartridge 400 slotting between corresponding ribs 515 in the bore 510. There are three sets of ribs 415, 515 arranged on each cartridge body 410 and in each respective bore hole 510, the respective sets being equidistantly spaced apart from each other circumferentially around the cartridge body 410 on the one hand and the bore hole 510
15 on the other; each set comprising a respective series of ribs 415, 515 arranged axially along the cartridge body 410 on the one hand and the bore 510 on the other.

When a capsule has been loaded into the central chamber, the six cartridges may be energised to drive the respective anvils onto the capsule from each of the six
20 directions. Load will thus be applied onto the capsule and onto the press frame (in the opposite direction) via the fastening mechanisms between the frame and the cartridges.

The same kind of radial fastening mechanism is provided at the front and back ends of
25 each cartridge to secure it radially to the front and back ends of each respective bore. The radial fastening mechanism is designed to allow the cartridge to be freely inserted into (and withdrawn from) the bore when in the unlocked condition and to prevent the radial displacement of the cartridge when in the locked condition. Transition between the locked and unlocked conditions will involved rotating the cartridge by 60 degrees
30 about its longitudinal axis. The radial fastening mechanism comprises three abutment lobes projecting radially outward from the cartridge and three corresponding abutment lobes projecting radially inward from the bore of the press frame. The three abutment lobes on the cartridge and on the press frame are equidistantly spaced apart around the circumference of the cartridge on the one hand and in the bore on the other. The
35 abutment lobes on the cartridge and frame are configured and dimensioned so that

when the cartridge is fully inserted in the bore and in the locked condition, the cartridge abutment lobes will radially abut those of the frame, the cartridge thus being prevented from substantial radial displacement.

- 5 When being inserted into the bore in the unlocked condition, the cartridge will be oriented with its abutment lobes circumferentially between those of the frame and there will be a clearance gap between the cartridge and the bore, including between their respective abutment lobes, so that the cartridge can be freely inserted and withdrawn without contacting the bore. Once inserted, the cartridge can be put into the locked
- 10 condition by rotating it by 60 degrees, causing the respective abutment lobes to abut each other radially. At the same time, the axial securement mechanism will be engaged.

Claims

1. A cartridge assembly comprising a chamber for containing hydraulic fluid, an intensifier element capable of reciprocating in the chamber and displacing the hydraulic fluid responsive to a drive means acting on the intensifier element, and a piston capable of reciprocating in the chamber and being displaceable responsive to a change in the pressure of the hydraulic fluid; the cartridge assembly configured so that when the pressure in the fluid increases responsive to a first force being applied by the drive means on the intensifier, the hydraulic fluid will exert a second force on the piston, the second force being greater than the first force; the mass of the hydraulic fluid being substantially conserved within the cartridge assembly.
2. A cartridge assembly as claimed in claim 1, for an ultra-high pressure generator apparatus.
3. A cartridge assembly as claimed in claim 1 or claim 2, in which the drive means is an electro-mechanical mechanism.
4. A cartridge assembly as claimed in any of the preceding claims, in which the intensifier element is an elongate member.
5. A cartridge assembly as claimed in any of the preceding claims, in which the intensifier element is attached at a proximate end to a ram external to the chamber, the ram being coupled to the drive means.
6. A cartridge assembly as claimed in any one of the preceding claims, comprising a housing, in which the drive means comprises a servomotor coupled to a threaded beam having a longitudinal axis, the position the beam being fixed relative to the housing; the servomotor and the beam arranged such that rotation of the beam about its longitudinal axis can be selectively driven by the servomotor; the intensifier element being driveably coupled to the threaded beam by means of a cooperatively threaded mechanism, such that rotation of the beam will result in a longitudinal force being applied to the intensifier element via the threaded mechanism.

7. A cartridge assembly as claimed in any of the preceding claims, comprising a housing, the housing comprising a guide bore for the intensifier element, the guide bore connecting the chamber with the outside of the housing; the intensifier element located in the guide bore arranged with a proximate end located outside the housing and a distal end located within the housing; the cartridge assembly comprising a seal means arranged with respect to the housing and the intensifier element such that hydraulic fluid is substantially prevented from escaping from the chamber while the intensifier element is capable of reciprocating in a guide bore.
8. A cartridge assembly as claimed in any of the preceding claims, comprising a housing, in which the piston has a proximate end located inside the chamber, the proximate end of the piston abutting a seat defined by an inner surface of the chamber when the piston is fully inserted into the housing.
9. A cartridge assembly as claimed in any of the preceding claims, in which the piston has a proximate end located inside the chamber and an opposite distal end, the piston comprising a receiver bore in the proximate end for accommodating a part of the intensifier element adjacent the distal end of the intensifier element.
10. A cartridge assembly as claimed in any of the preceding claims, comprising a housing, in which the housing comprises a guide bore for the intensifier element and the piston comprises a receiver bore in the proximate end of the piston for accommodating a part of the intensifier element adjacent the distal end of the intensifier element, the guide bore and the receiver bores being aligned such that the intensifier element can extend from the guide bore and into the receiver bore.
11. A cartridge assembly as claimed in claim 10, in which the receiver bore and guide bore are in communication with each other and substantially all hydraulic fluid in the chamber is contained in a volume defined by the guide bore and the receiver bore when the piston is fully inserted into the chamber.

12. A cartridge assembly as claimed in any of the preceding claims, comprising an anvil for impinging a body to be pressurised, the anvil mounted onto the distal end of the piston.
- 5 13. A cartridge assembly as claimed in claim 12, in which the anvil is mounted onto an anvil holder, which is mounted onto a position adjustment mechanism for adjusting the position of the anvil in the lateral plane, which is mounted onto the distal end of the piston.
- 10 14. A cartridge assembly as claimed in any of the preceding claims, comprising a housing, in which the housing is configured for insertion into and coupling to a bore provided in a frame for a press apparatus.
- 15 15. A cartridge assembly as claimed in claim 14, in which press apparatus is for the synthesis and or sintering of super-hard material such as diamond or cubic boron nitride (cBN) material.
- 20 16. A press system comprising a press frame and a cartridge assembly as claimed in any one of claims 1 to 15.
17. A press system as claimed in claim 16, comprising six cartridge assemblies as claimed in any one of claims 1 to 15.
- 25 18. A press system as claimed in claim 16, comprising four cartridge assemblies as claimed in any one of claims 1 to 15.

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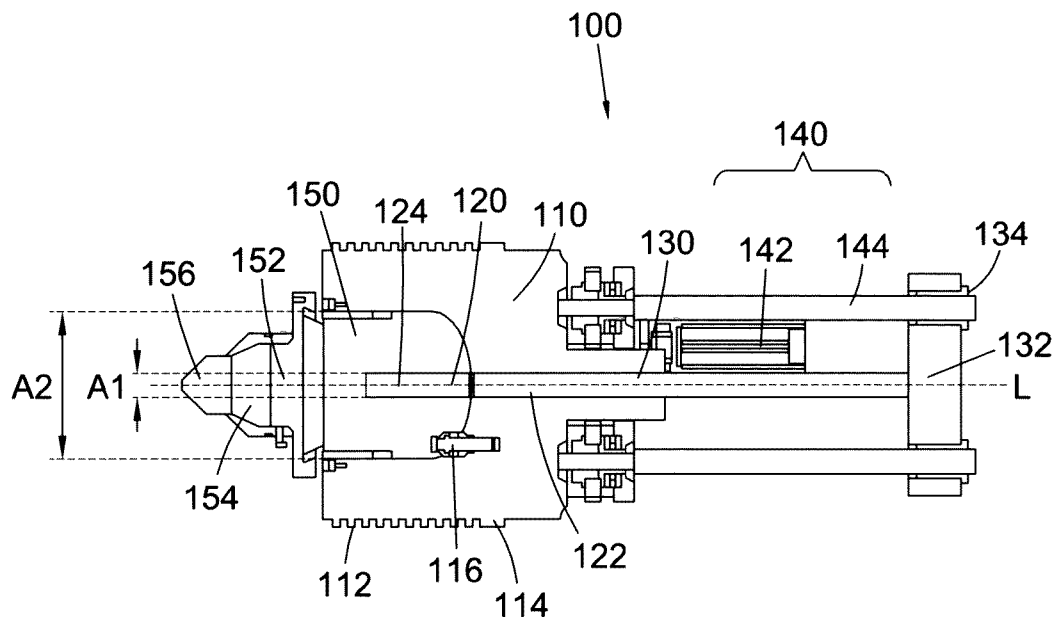


Fig. 1A

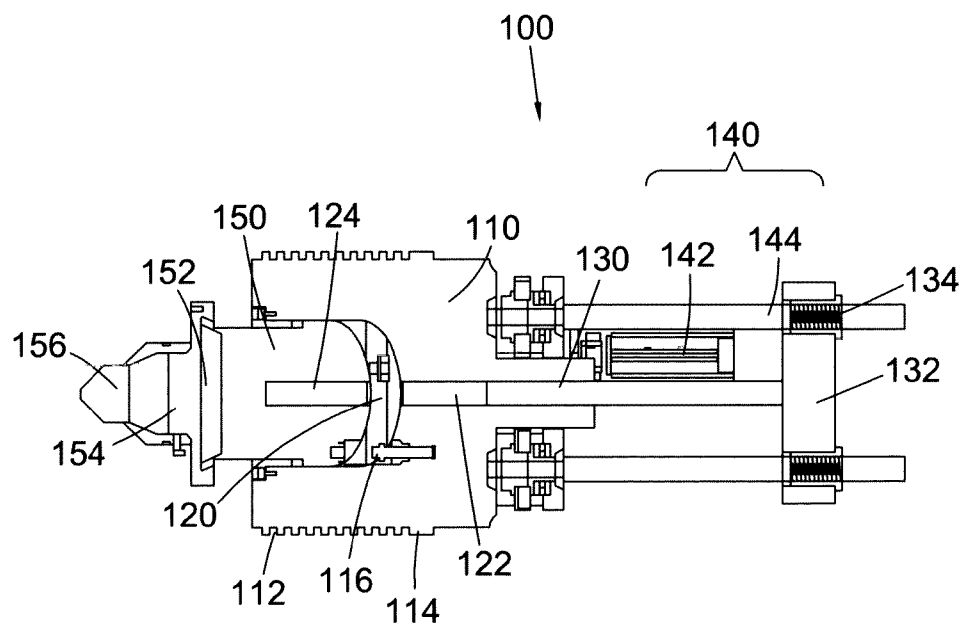


Fig. 1B

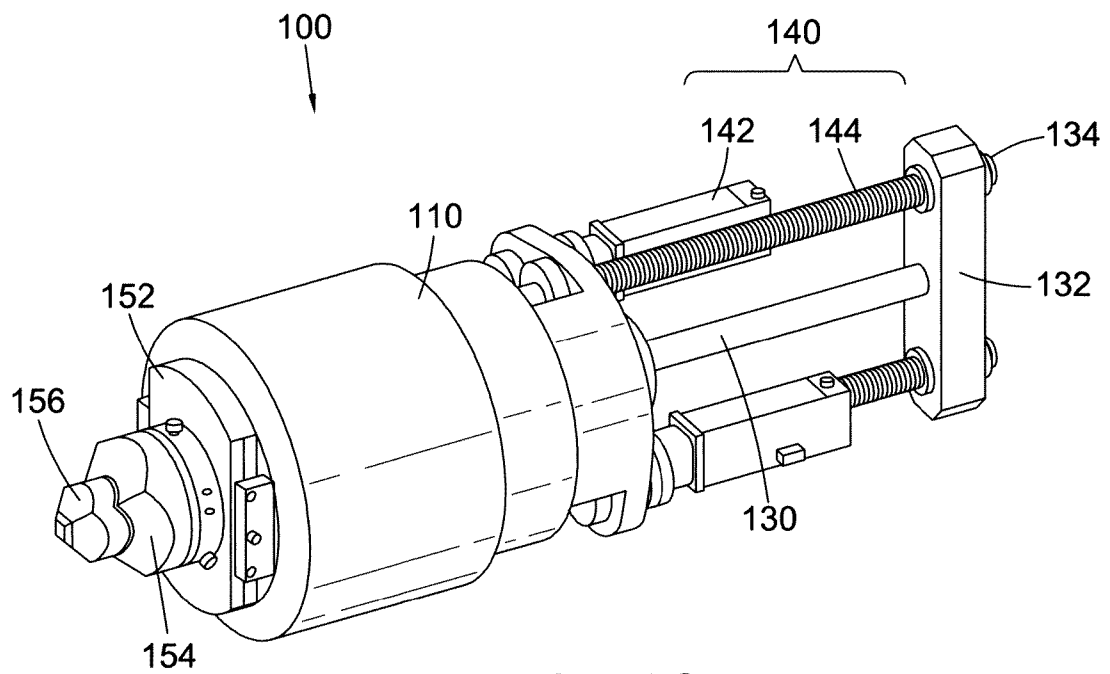


Fig. 1C

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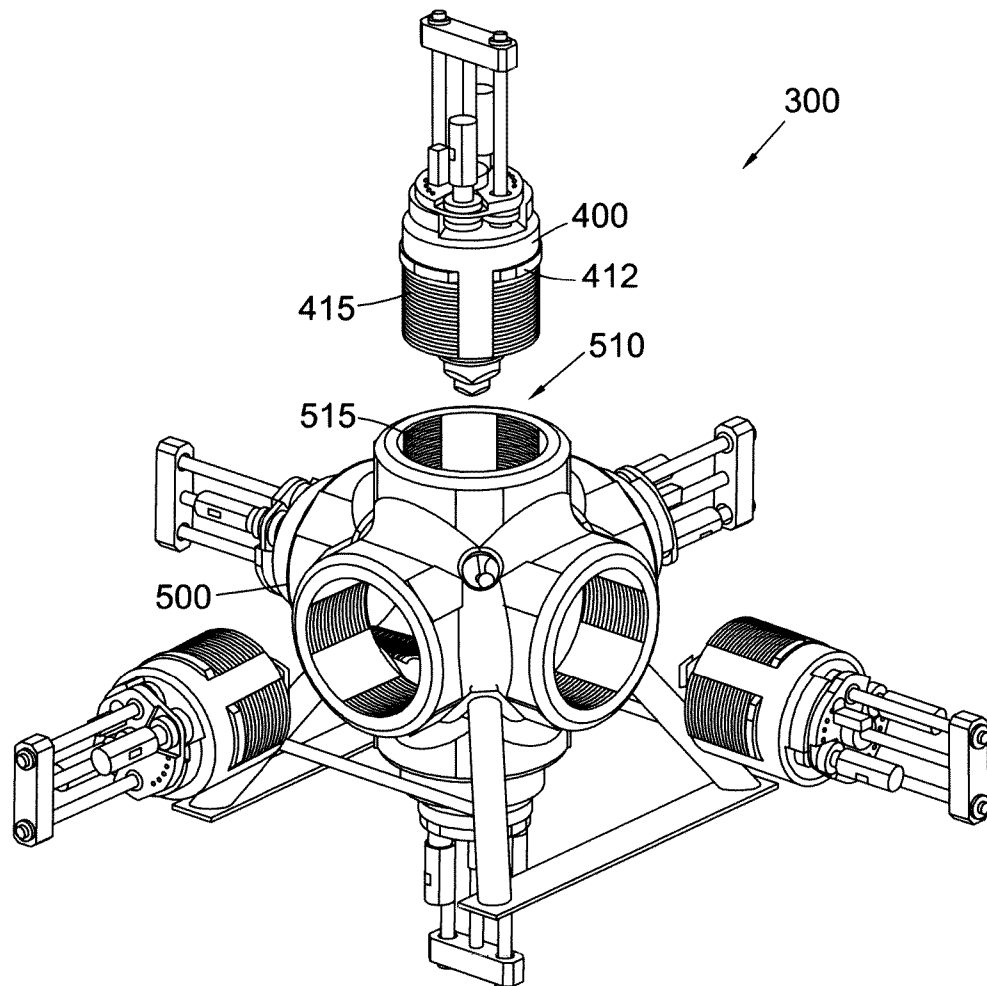


Fig. 2A

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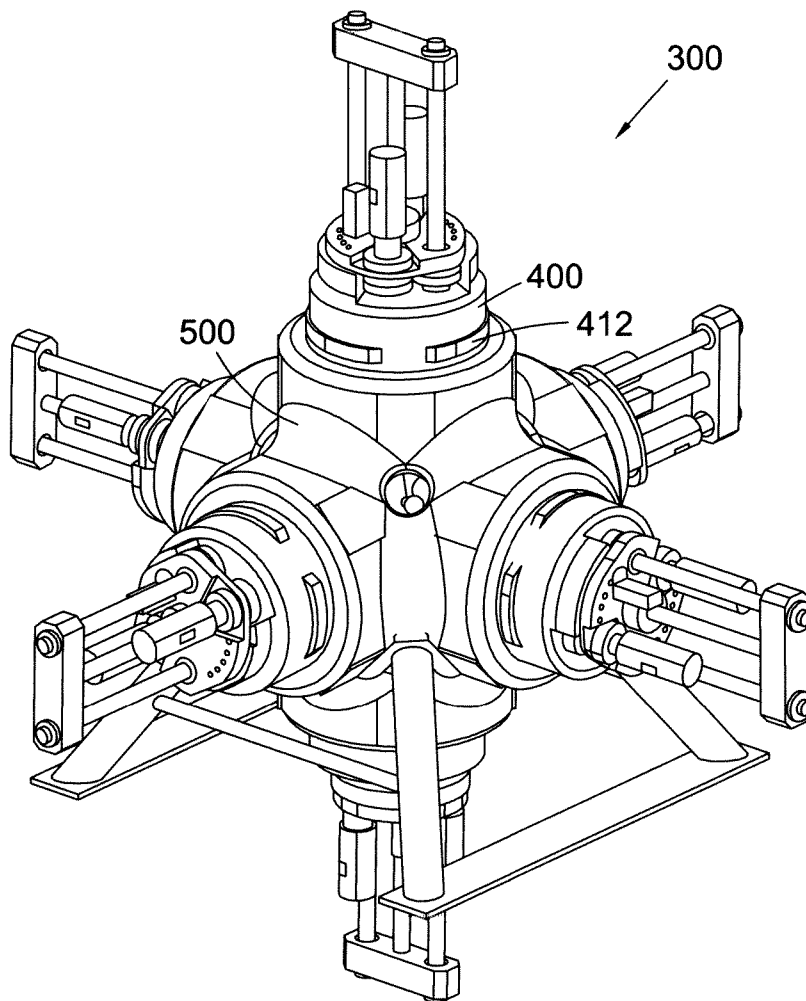


Fig. 2B

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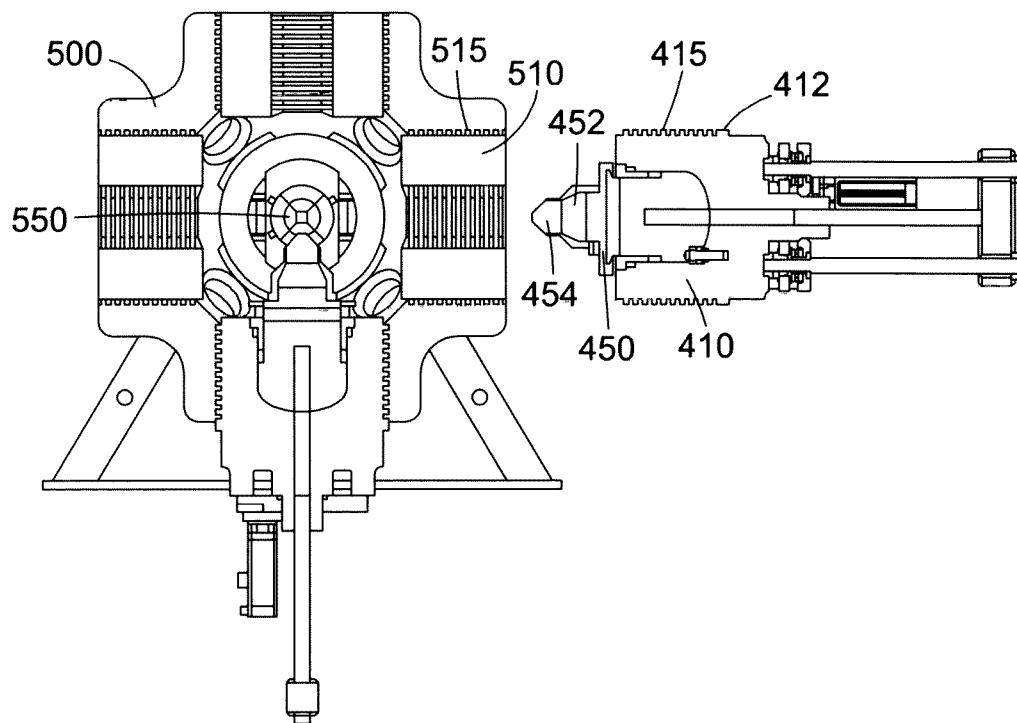


Fig. 2C

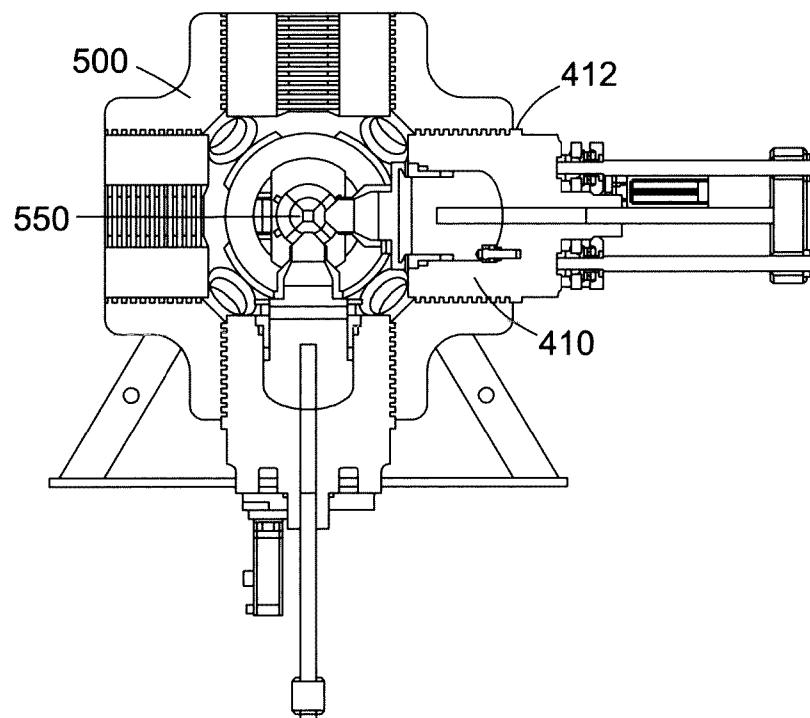


Fig. 2D

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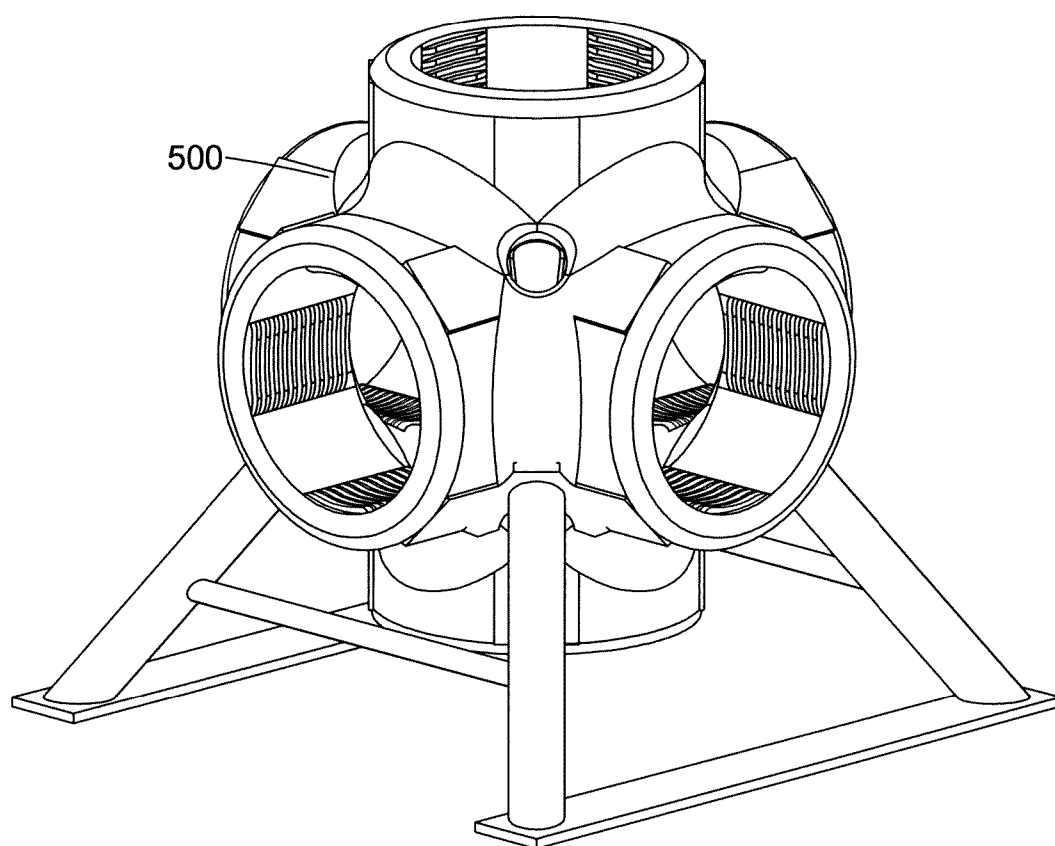


Fig. 2E

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2013/056088

A. CLASSIFICATION OF SUBJECT MATTER
INV. B30B11/00
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B30B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2007/040140 A1 (HALL DAVID R [US] ET AL) 22 February 2007 (2007-02-22) figures	1-5,7-18
X	----- ITO E ET AL: "A new 6-axis apparatus to squeeze the Kawai-cell of sintered diamond cubes", PHYSICS OF THE EARTH AND PLANETARY INTERIORS, ELSEVIER, AMSTERDAM, NL, vol. 174, no. 1-4, 1 May 2009 (2009-05-01), pages 264-269, XP026091943, ISSN: 0031-9201, DOI: 10.1016/J.PEPI.2008.11.007 [retrieved on 2008-11-25] page 2 - page 3; figures 2-4 ----- -/-	1-18



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

12 June 2013

Date of mailing of the international search report

20/06/2013

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Baradat, Jean-Luc

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2013/056088

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6 336 802 B1 (HALL DAVID R [US]) 8 January 2002 (2002-01-08) cited in the application claims; figures -----	1-5,7-18
X	US 2002/025354 A1 (HALL DAVID R [US]) 28 February 2002 (2002-02-28) figures -----	1-5,7-18
A	JP 2006 175297 A (SUMITOMO HEAVY IND TECHNO FORT) 6 July 2006 (2006-07-06) abstract; figures -----	6

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2013/056088

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