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(54) **Title**: AUTOMATIC GAS CYLINDER FILLING FACILITY

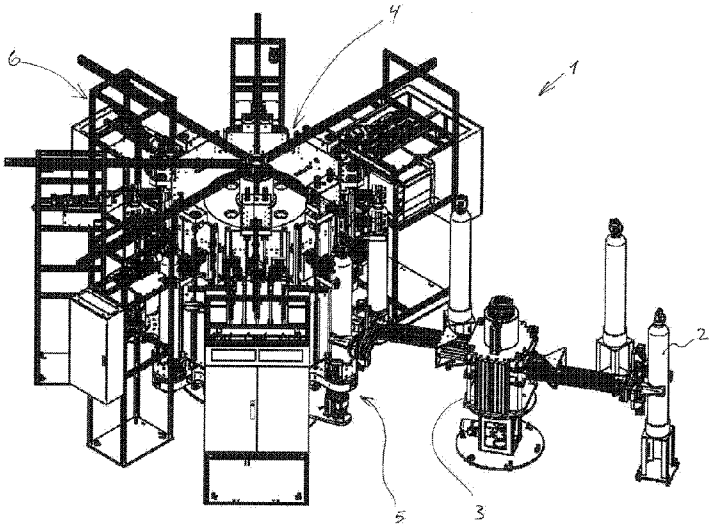


Fig 1

(57) **Abstract**: The invention concerns a method for filling gas on gas cylinders with pressures greater than 50 bar in an automatic gas cylinder filling facility, the method including at least the following steps: a gas cylinder is placed in a filler carousel, the gas cylinder is positioned by means of a geometric positioning system, a filler adapter is fitted, and the gas cylinder is filled, whereby it is achieved that the filling can be effected fully automatically without an operator, thereby eliminating ergonomic problems and safety issues by having any persons close to the gas filling of cylinder with pressures up to e.g. 300 bar.

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Automatic Gas Cylinder Filling Facility

Field of the Invention

The present invention concerns a method for filling gas on gas cylinders with pressures greater than 50 bar in an automatic gas cylinder filling facility, an automatic gas cylinder filling facility and use of an automatic gas cylinder filling facility.

Background of the Invention

Gas cylinders with pressures over 50 bare are presently filled entirely manually. The applied method entails that the cylinders are to be sorted such that they have the same height, diameter and same content in the cylinder. It is an extensive manual work in which the cylinders are to be lifted out of the baskets in which they are transported. When the cylinders have been sorted and have the same height, diameter and contents, they are lifted in baskets up to the defined height where filler adapters for screwing on the valves are suspended vertically and are here screwed on manually. The filling is commenced, taking typically 10-15 minutes for 12 cylinders, depending on the size and contents of the cylinders. The filler adapters are screwed off the cylinder valves manually, and the filled cylinders are moved away.

Gas cylinders for industrial and medical use are typically steel cylinders, aluminium cylinders or composite cylinders that are filled to pressures of 200 or 300 bar. The cylinders exist in a number of different sizes from 1 litre up to 80 litres. This means that there is a great variation in diameter and height, and of course weight. The heaviest cylinders weigh up to 100 kg, and the lightest down to 1.5 kg. The light cylinders are typically those used for medical gases for the reason that they in some situations are carried by the user.

By industrial gases there is great variation in the gases and gas mixtures that are sold. This is typical since by welding and cutting in metals there is to be exactly the right gas or gas mixture for the material to be processed. There are more than 150 different products, i.e. gases and gas mixtures, on the market.

The number of variants is less for medical gases; the standards describe 9 different types of gases, meaning gases and mixtures of gases. However, the variation in the consumption to be delivered by cylinder and valve is very great. This is due to the fact

that patients are very different, as new-born infants, adult males and women require very different dosage of oxygen and anaesthetic gases. The issue here is the many different flow settings going from 0.1 l/min up to 25 l/min, with a large number of different settings there between.

The gas cylinders are filled with gas by the gas companies, and the cylinders are typically distributed to the customers by car and are typically also collected by car. A gas company can have a number of filling stations in a country, depending on the size of the country and the number of gas cylinders in use. A typical filling station for industrial use fills from 500,000 to 2,000,000 cylinders per year. As an average, an industrial cylinder of 50 litres is typically filled two times a year. Medical cylinders are typically filled four to eight times a year, given that they are somewhat smaller in volume.

Before starting the filling operation, the cylinders are sorted such that they all have the same height and diameter. They are also sorted such that the contents are the same in all cylinders.

All cylinders are placed in a basket before filling. The basket has the purpose of enabling transport of several cylinders in a secure and economical way. The basket is also used during filling, where the filling starts by elevating the basket such that all the cylinder valves are at the same height. This means that a basket with low cylinders are lifted higher than a basket with high cylinders. An operator now screws a filler adapter on the discharge thread of each single valve, forming a pneumatically tight connection between the filler adapter and the valve until all the cylinders, typically 12 or 16 cylinders, are connected to the same manifold.

The process that is initiated is therefore as follows:

a. The cylinder is emptied of the residual gas remaining in the cylinder. The valve is opened by a handwheel, and the residual gas flows out. In case of a corrosive or poisonous gas, the gas is collected; otherwise it is discharged to the atmosphere.
b. The consumer is not allowed to empty the cylinder entirely of gas by himself. There is to be a so-called residual gas pressure, a minimum of 3.5 bar left in the

cylinder when returned to the gas company. This is checked by a pressure measurement.

c. A vacuum pump is now operated in order to get all moisture out of the cylinder as moisture implies and causes corrosion in steel cylinders.

d. The filling by the first component, e.g. argon or nitrogen, is commenced. In case of a single gas, obviously only this component is filled.

e. The filling is finished when a pressure at a certain temperature is reached. Curves depicting temperature and pressure are followed here.

f. When the filling is finished, the valve is closed and the filler adapter is dismounted.

g. A check of possible leakage is normally performed by means of a leak spray.

h. The cylinder is sealed in various ways as a guarantee for the consumer who then can ascertain if the cylinder has been used or not.

i. The filled basket is now moved to the departure site.

j. A process of taking the cylinders out of the basket is now commenced, depending on what each lorry is to take to the consumers.

For medical cylinders there are a number of additional conditions:

a. The cylinders exist as small (e.g. 0.5 litre) and large (e.g. 20 litre) sizes of cylinders among each other. The cylinders are to be carried, and composite materials and aluminium are therefore used. The cylinders are moved on carts at the hospital or are suspended on the bed when a patient is moved.

b. The cylinders are filled with 200 bar, though filling pressures of 300 bar are about to be more widely used.

c. Filling cylinders with oxygen or mixtures with oxygen is associated with high risk. This is due to the fact that oxygen is self-igniting by a so-called adiabatic process.

d. All equipment used for filling and the products themselves are tested by independent authorities or other authorised organisations.

A medical cylinder comprises a valve and a cylinder as well as the contents. The content of the cylinder is regarded as a medicament and is covered by rules for medicaments. Valve and cylinder are regarded as medical equipment and is to be

labelled according to various directives and standards in Europe. The modern valves include a valve with shutoff for the cylinder, a pressure regulating unit and a unit for setting various flows.

The present processes for filling and check of medical gases include:

a. Cleaning, since valve and cylinder are often smeared with blood. A comprehensive work with protecting staff against infections is performed here.
b. The cylinder is filled with the specified gas, and it is stringently checked if the labelling on the cylinder corresponds to the contents.
c. Checking that the manometer indicates correct pressure as accidents have occurred where a patient believes that a cylinder is full while in reality it is empty.
d. Flow and pressure measurement at the discharge connection (4.5 bar discharge connection). The standards prescribe that pressures are to be within certain limit values.
e. Flow check. The valve normally has 12 settings including zero setting which are to be checked.
f. The moment to be applied for turning the flow control knob is not to be too great as many elderly people only can turn the knob if it is easy to turn.
g. Leak check. The shutoff device for the cylinder is to be checked as to gas tightness.
h. External leakage check when the valve is open.
i. The shutoff device is to be checked whether it is closed with the correct moment and whether it is easy to operate.
j. The filler neck is to be checked if it is correctly secured with a sleeve and such that it cannot be accessed by a user.
k. All these functions are performed manually and full documentation and traceability as to their being performed is to be provided.

The present methods are costly, and lot of handling of cylinders is required, such as manual screwing the filler adapter on and off. There are also a number of ergonomic problems due to all the screwing movements that an operator has to do by hand. There are, however, screwguns for the operator's use, but the operator is typically to catch the screw thread first before he is able to use the screwgun or a pneumatic spanner.

The leakage check with leak spray is not performed in some cases since it is time-consuming to stand looking at soap bubbles.

The residual gas check cannot be performed as required by the rules, as all cylinders are connected to the same manifold and each cylinder is therefore not checked separately, but all cylinders, typically 12 or 16 cylinders, are checked at once. The residual gas function is essential as the time limit for checking cylinders is up to 15 years. This is a consequence of the valve having a residual gas function, thereby ensuring that no moisture can enter the cylinder as there is always a positive pressure in the cylinder, meaning that the cylinder cannot be emptied.

However, there are also automatic solutions for LPG (liquid petroleum gases); these are, however, only for low pressures up to 16 bar.

Documentation is required for pressurised equipment in Europe, where everything associated with pressure, from requirements for the packing (the cylinder) and the valve, is to be documented. The re-test period for the cylinder is also determined, depending on the type of gas in question. The re-test period runs from 5 years up to 15 years, depending on the gas type. It is also required that leaks are to be documented. The residual gas function is part of the valve, and requirements specification are here determined as to what is to be tested by the gas companies.

However, the gas companies have a problem with documenting the residual gas function, the leakage and the purity of the gas (5 ppm or 100 ppm). This problem is related to the way of filling where the cylinders are filled through a common manifold, and thereby it is impossible to check and document each cylinder separately.

Object of the Invention

The invention has the object, among others, of providing documentation of the following:

a. The moment applied for opening and closing the valve of the cylinder. ADR (*Accord européen relatif au transport international des marchandises Dangereuses*

*par **Route***) refers here to valve standards (ISO 10297) in which requirements for moment are described.

b. The leakage when the valve is closed and ready for transport. At the moment, this can only be measured by leak spray, which does not give any value, only a subjective assessment. Here ADR refers to valve standards in which leakage requirements are indicated as a maximum leakage of 6 cm^3/min. The value is even lower for poisonous gases.

c. The residual gas function where closing pressure and opening pressure are to be documented. This cannot be measured today as filling is performed through manifold, thereby measuring several cylinders at a time. Closing pressure is to be at least 3.5 bar, cf. ISO 15996.

d. Purity of the gas. Gases are currently supplied as pure gases of different degrees of purity. Gases for laboratories are typically gases better than 5 ppm. Common industrial gases are 100 ppm or even worse. In order to document this quality, a sample of the gases is taken and analysed by a laboratory which is part of the filling station. However, only one sample can be taken for all cylinders connected to the manifold. This means that an unambiguous documentation for each single cylinder is not provided. If this is to be achieved, each single cylinder has to go past the laboratory which is too cost-demanding. By the carousel each single cylinder can be measured online while being filled and data can be stored under the running number of the cylinder.

e. The moisture content of the filled gas is to be very low and to be documented. If too high, corrosion starts inside the cylinder. By the present filling method across a manifold it cannot be documented. By this method, each single cylinder is evacuated and the moisture in the gas drawn out of the cylinder is measured. Thereby is provided 100% documentation and data which are stored under the running number of the cylinder.

f. The cylinder is to be sent to inspection every 5, 10 or 15 years, as stated by ADR. This inspection is partly a visual inspection of the external surface where i.a. corrosion, impact marks and scratches are to be noted. If the cylinder is damaged according to this assessment, the cylinder is painted. The cylinder is checked internally in two different ways which are approved by law.

i. Method 1 is a hydraulic test of the cylinder with water. The cylinder is pressurised to e.g. 450 bar, then the cylinder is emptied of water and dried by

heat such that no moisture is left. The cylinder is now leak tested, typically with nitrogen which is very dry.

ii. A second method is by ultrasound. Here, the material thickness of the steel or aluminium is measured. This is performed by rotating the cylinder and an ultrasound device is moved up and down the surface of the cylinder. If the material thickness is less than specified for the cylinder in question, the cylinder is scrapped.

g. The filling carrousel provides the option of rotating the cylinder by a motor and placing an ultrasound device which is moved up and down the cylinder, measuring the material thickness. A cylinder can thereby be tested each time it proceeds to filling without an extra cost.

h. The filling carrousel can also perform the external inspection of the surface of the cylinder. This can be done by a 3D camera that scans the surface while the cylinder is rotated.

i. By these inspection methods, the gas companies can save much time and money, and at the same time the safety of pressurised cylinders will be considerably improved.

The invention has also the object of filling and checking the medical gases such that:

a. The filling carrousel can be used for testing and performing all functions, as mentioned, in an economical and safe way. The cylinders can be mounted and, depending on their size, be elevated to a position where they can be automatically filled.

b. The entire cylinder and valve can be rotated 360° such that discharge connection, flow outlet, manometer and flow adjusting knob can be accessed.

c. The valve is opened automatically, and the cylinder can be rotated into position.

d. The discharge connection can be connected automatically, and pressure and flow be measured by rotating the cylinder so that the gate stands oriented.

e. The flow outlet can be connected automatically by rotating the cylinder. The rotary knob for flow can be connected afterwards and rotated to all 12 positions. The flow can be measured, and there is no flow when the various positions are accessed. The moment is checked at the same time.

f. The cylinder can be cleaned by a nozzle and the cylinder rotated simultaneously. Cleaning can thereby be effected in corners where it otherwise can be difficult to get in. The cleaning medium can be water vapour. Drying can be performed by a dry gas such as nitrogen.

g. The manometer is checked by turning the cylinder such that the manometer stands correctly positioned in relation to a camera that takes a picture of the position of the pointer, thus providing documentation of correct indication. Some cylinders have a digital manometer. Here, the camera can also take a picture and thereby provide documentation that the number appears correct.

h. The shutoff device may be of different types. Handwheel via rotation, lever arm with several positions, or a pushbutton. The invention has the object of being able to operate all types of shutoff devices.

The solution to these challenges is changing to single cylinder filling, but such that it will be an economical solution with sufficient capacity at the same time. This means that the rate is to be rather high, with a capacity of at least 200,000 fillings per year in a facility.

The result of a study and comparison of methods and the economic advantages of the present methods by manual filling and with the methods of the invention with automatic filling with cylinder handling by a filling carrousel appears from the table below:

Cycle time comparison between manual and automatic filling by carrousel			
	Present method with manual filling	Automatic filling by carrousel and cylinder handling	Difference
Operation	Step time in seconds/cylinder	Step time in seconds/cylinder	Seconds/ cylinder
Moving cylinders from basket to transport and basket to filling	72	0	
Emptying cylinder	10		
Checking residual gas function	20	120	

Filling itself, incl. vacuum, moisture, filling, sealing	50		
Moving cylinders to basket for transport	72	0	
In total	224	120	104

Thus there is a saving of 104 seconds per cylinder. At a capacity of 200,000 filling/year, the saving per year becomes: 200,000 x 104 seconds/cylinder = 5,777 hours/year.

The time saving by one filling, thereby increasing capacity, and the saving of an operator's pay for 5,777 hours/year thereby provides the invention as a justifiable solution economically as well as capacitywise. To this is added the following advantages:

Full flexibility between large and small cylinders. Therefore a minimum of changeover time.

Fully automatic filling without operators. This eliminates the ergonomic problems and the safety issues of having people close to the filling of cylinders with pressure up to e.g. 300 bar. Some of the gases are also self-igniting, such as oxygen.

Moreover, the invention opens for automatic diagnostic of the condition of the cylinder, externally as well as internally, thereby saving the very costly re-testing of the cylinder typically every 15 years. The invention hereby provides possibility of scanning the surface externally and analysing the material thickness of the steel/aluminium by scanners and ultrasound.

The invention is completely unique given that there is no solution to filling industrial and medical gas cylinders with high pressure of e.g. 200 and 300 bar. Currently there are only automated facilities for LPG (liquid petroleum gases), which are cylinders for combustible gases typically used e.g. for a garden grill. These cylinders are filled with liquid LPG gas, and the pressure is 16 bar at normal temperature, where cylinders are filled manually in e.g. pallets, where an operator is to mount/dismount filler adapters, open/close the valves manually or by means of a tool such as a spanner.

Description of the Invention

According to a first aspect of the invention, the above mentioned object is achieved by a method for filling gas on gas cylinders with pressures greater than 50 bar in an automatic gas cylinder filling facility as described in the introduction and in the preamble of claim 1, the method including at least the following steps:

a. a gas cylinder is placed in a filling carousel;
b. the gas cylinder is positioned by means of a geometric positioning system;
c. a filler adapter is mounted on the gas cylinder;
d. the gas cylinder is filled; and
e. the valve is closed with a certain moment after filling.

This enables filling the intended gas on the desired gas cylinder in a safe way. This can be done by means of filling stations on the filling carrousel whereby the step time is kept down. By the capacity of the filling carrousel, where all cylinders can be filled without regard to height and diameter, the solution is furthermore economically attractive. In addition, the filling can be effected fully automatically without an operator, thereby eliminating ergonomic problems and safety issues by having any persons close to the gas filling of cylinder with pressures up to e.g. 300 bar.

According to a second aspect, the invention also concerns a method for filling gas on gas cylinders with pressures greater than 50 bar in an automatic gas cylinder filling facility, wherein the placing of the gas cylinder in the filling carrousel includes placing in the loading station of the filling carrousel, wherein step a. of the method further includes at least the following step:

- the gas cylinder is retained at the bottom and at the top by means of retaining devices.

This enables retaining the gas cylinder in a fixture during the entire process in the gas filling facility, and such that the cylinder can safely rotate 360° clockwise or counterclockwise, and furthermore can be moved up and down without any hazard to the surroundings.

According to a third aspect, the invention also concerns a method for filling gas on gas cylinders with pressures greater than 50 bar in an automatic gas cylinder filling

facility, wherein the gas cylinder is stepped to the first filling station, wherein method step b. further includes at least the following steps:

- a height adjusting sensor detects the height of the gas cylinder, where the height is roughly adjusted by means of motors driving the retaining devices and thereby the gas cylinder up or down, depending on the height detected by the adjusting sensor;
- a measuring unit measures the valve on which the filler neck is located, after which the gas cylinder is rotated by means of a motor to a position at which the filler neck of the gas cylinder is perpendicular to the measuring unit;
- the measuring unit then measures the vertical position of the valve, and the height is fine-adjusted by means of the motors driving the retaining devices and thereby the gas cylinder up or down, depending on the height detected by the measuring unit; and

  the measuring unit measures the horizontal displacement of the valve.

This enables elevating a cylinder to a very defined position at which the filling connection of the cylinder valve is positioned within a tolerance of +/- 0.05 mm along the X-, Y-, and Z-axes and the axis of rotation C. This is enabled by measuring the vertical position of the cylinder valve by a sensor, after which a signal is transmitted to a motor which then moves the cylinder up or down to the desired position.

By a measuring unit is here meant either a measuring unit that is physically functioning by contact, e.g. by means of a sensor finger, or a touch-free sensor unit operating without contact, e.g. by using a laser. One advantage of the touch-free sensor units is that they may contribute to keep the step time low.

In a method and an embodiment of an automatic gas cylinder filling facility there is only used measuring units that operate by physical contact; in a second method and a second embodiment of an automatic gas cylinder filling facility there is only used touch-free measuring units; and in a third method and a third embodiment of an automatic gas cylinder filling facility there is used a combination of such measuring units.

Measuring sensors for the X-, Y-, and Z-axes now detects the filler neck of the cylinder valve with a measuring unit, after which a motor rotates the gas cylinder until

the discharge connection now is standing perpendicularly to the filling station. Motors are elevating and lowering the gas cylinder along the Z-axis as well.

A measuring sensor indicates how large the discharge connection is in the X- and Y-directions, and the controller now knows precisely where the cylinder valve is positioned in a 3-dimensional coordinate system. All positions become fixed when they are found.

In case that the horizontal displacement deviates too much, cylinder and valve are scrapped as the cylinder and the valve cannot be moved horizontally within the stations. Detection of the displacement occurs in relation to the centre line where valves that are too much off the centre are scrapped. Offline valves with the filler neck off centre can, however, be operated anyway as the subsequent stations can be arranged such that they move horizontally.

According to a fourth aspect, the invention also concerns a method for filling gas on gas cylinders with pressures greater than 50 bar in an automatic gas cylinder filling facility, wherein a filler adapter is fitted with screw thread corresponding to the gas in question, wherein method step c. further includes at least the following steps:

- the filler adapter is picked up automatically and screwed on the filler neck of the valve automatically as the position of the valve is completely known and fixed;
- a bushing with an O-ring connection is moved automatically in over the filler adapter and performs a completely pneumatically tight connection; and

the applied moment is monitored during the screwing on of the filler adapter.

This will enable automatic screwing on of a filler adapter when the cylinder valve is positioned and the screw thread on the cylinder valve is caught. If the cylinder valve was not correctly positioned, this would not be possible.

When the filler adapter is on the valve, the filler adapter can be connected on all subsequent station and be filled with gas at pressures greater than 50 bar. By the present invention, the cylinders are filled one by one in different steps.

The filler adapters are disposed in the vicinity of the gas cylinder valves such that they can be gripped and screwed into the filler neck of the cylinders. Filler adapters with

different connecting threads can therefore be mounted, and since they sit in a holder they can easily be fetched automatically and also be screwed on automatically. After use they are screwed off and placed again in respective holders.

A filler adapter is mounted automatically with different screw thread depending on national standard for the gas in question. The filler adapter is connected with a ball lock that can withstand pressures over 500 bar.

With full check on moment by the screwing on of the filler adapter it is ensured that the bad screw threads are scrapped, i.e. bad threads on the filler adapters as well as in the valves.

According to a fifth aspect, the invention also concerns a method for filling gas on gas cylinders with pressures greater than 50 bar in an automatic gas cylinder filling facility, wherein before, during and after method step d. in which the gas cylinder is filled, the method further includes at least one of following steps, which is documented:

- the valve of the cylinder is closed by a given moment;
- the valve is closed and tested for leaks;
- the purity of the gas and the moisture content of the gas is measured.

This enables providing documentation of the conditions for each individual gas cylinder as the measurements are performed online before, during and after the filling of the gas on cylinders, and data are stored under the running number of the cylinder for use as documentation.

According to a sixth aspect, the invention also concerns a method for filling gas on gas cylinders with pressures greater than 50 bar in an automatic gas cylinder filling facility, wherein the gas cylinder is filled, where the method after step d. further includes at least one of following steps:

- the cylinder is rotated by means of a motor and an ultrasound device is moved up and down the cylinder, measuring the material thickness;

- the cylinder is rotated by means of a motor and an external inspection of the surface of the cylinder is performed by a 3D camera.

This will enable testing of a cylinder each time the cylinder is filled without additional cost, where the material thickness of the cylinder is measured and/or the surface of the cylinder is scanned for corrosion, impact notches and scratches, whereby an automatic diagnosing of the condition of the cylinder can be performed externally as well as internally, thereby substituting the costly re-testing of the cylinder.

According to a seventh aspect, the invention also concerns an automatic gas cylinder filling facility for filling gas on gas cylinders with pressures greater than 50 bar, wherein the facility includes a filling carousel with at least one filling station, where the at least one filling station includes at least one gas cylinder retaining device, a geometric gas cylinder positioning system, a filler adapter and a gas filling unit.

This enables simultaneous and automatic filling of several gas cylinders, wherein the gas cylinders are retained in a secure mounting during the whole process in the gas cylinder filling facility, and where the gas cylinders are positioned such that the filler adapter can be screwed on the gas cylinder and such that the gas cylinder can be filled as described under the method.

According to an eighth aspect, the invention also concerns an automatic gas cylinder filling facility for filling gas on gas cylinders with pressures greater than 50 bar, wherein the facility further includes a cylinder placing and removing unit and a loading station.

This enables handling of the gas cylinders by the cylinder placing and removing unit before they are filled in the gas cylinder filling unit and after they have been filled in the gas cylinder filling unit, where the cylinder placing and removing unit positions the gas cylinders in the loading station.

According to an ninth aspect, the invention also concerns an automatic gas cylinder filling facility for filling gas on gas cylinders with pressures greater than 50 bar,

wherein the geometrical positioning system at least includes a height adjusting sensor and a filler neck positioning unit with a measuring unit.

This enables measuring the vertical position of the cylinder valve by a sensor, after which a signal is transmitted to a motor which then moves the cylinder up or down to the desired position.

The filler neck positioning unit then detects the filler neck of the cylinder valve with a measuring unit, after which a motor rotates the gas cylinder clockwise or counterclockwise, depending on what is most expedient, until the discharge connection now is directed perpendicularly to the filling station. In addition, the gas cylinder position is fine-adjusted in that motors lift and lower the gas cylinder according to the signals of the measuring unit.

In a tenth aspect, the invention also concerns use of an automatic gas cylinder filling unit for filling gas on gas cylinders with pressures greater than 50 bar according to the method claims 1 to 6 and the facility according to claims 7 to 9 for filling gas cylinders with medical gases.

The invention also concerns a system for controlling and regulating the facility, including various technical elements such as microprocessors, sensors, timers, motors and actuators, all of which are not mentioned in the description but which the skilled in the art will understand are necessary for invention to operate according to purpose.

Description of the Drawing

The invention will now be explained more closely in the following by description of non-limiting embodiments with reference to the drawing, where:

Fig. 1 shows a perspective view of a gas cylinder filling facility;

Fig. 2 shows a detail of the facility with a loading station and a filling station in perspective view;

Fig. 3 shows a perspective view of the filling carrousel of the facility;

Fig. 4 shows a perspective view of one of the stations in the facility;

Fig. 5 shows a perspective view of an upper retaining device of a station with filler adapters;

Fig. 6 shows a station with measuring equipment, screwgun and gas filling unit viewed from above;

Fig. 7 shows measuring equipment, screwgun and gas filling unit in perspective view;

Fig. 8 shows a perspective view of a height adjustment sensor;

Fig. 9 shows a perspective view of a filler neck positioning unit;

Fig. 10 shows a perspective view of a screwgun;

Fig. 11 shows a perspective view of a gas filling unit;

Fig. 12 shows a perspective view of a unit on a gas cylinder with i.a. manometer.

List of designations

1	gas cylinder filling facility
2	gas cylinder
3	cylinder placing and removing unit
4	filling carrousel
5	loading station
6	filling station
7	rotary positioning motor
8	height positioning motor
9	vertical axis of rotation
10	lower retaining device
11	upper retaining device
12	rotating device
13	support holder
14	spindle
15	slide
16	filler adapter
17	filler neck
18	flow regulation
19	protection device
20	first gripper
21	second gripper

22 roller
23 slide
24 height adjusting sensor
25 filler neck positioning unit
26 screwgun
27 gas filling unit
28 cylinder valve opening/closing unit
29 measuring unit
30 flow outlet
31 discharge connection
32 manometer
33 handwheel shutoff
34 non-return valve

Detailed Description of Embodiments of the Invention

On Fig. 1 appears an automatic gas cylinder filling facility 1 where a gas cylinder 2 by means of a gas cylinder placing and removing unit 3 is supplied to a filling carrousel 4 by placing in a loading station 5, from where it is later stepped to the various filling stations 6 of the filling carrousel.

A detail of the facility 1 with a loading station 5 and a filling station 6 is seen on Fig. 2,
where a rotary positioning motor 7 is disposed under the cylinder 2, whereas a height positioning motor 8 is disposed above the cylinder 2.

The filling carrousel 4 of the facility is seen on Fig. 3, the part of the facility 1 rotating about a central vertical axis of rotation 9, whereas the remaining part of the facility 2 is stationary. It appears that there are eight stations on the shown filling carrousel 4, namely loading station 5 and seven filling stations 6, with a cylinder 2 placed on the shown stations.

On Fig. 4 appears one of the stations of the facility, where a cylinder 2 is placed and retained by a lower retaining device 10 and an upper retaining device 11. The lower

retaining device 10 is connected to the shown rotating device 12 driven by a rotary position motor 7 (shown on Fig. 2). The lower retaining device 10 is also connected to a support holder 13 which by means of the spindles 14 driven by the height positioning motor 8 (shown on Fig. 2) can be moved up and down along the rails 15.

At the top, the Figure shows a number of filler adapters 16 disposed at either side of the filler neck 17 of the cylinder, flow regulation 18 and protection device 19 in the form of a bracket.

On Fig. 5 appears an upper retaining device 11 of a station with filler adapters 16. As it appears from the Figure, the upper retaining device 11 includes a first gripper 20 and a second gripper 21, both with two rollers 22 such that the cylinder 2 is held between the four rollers 22 in total. The rollers 22 enable rotation of the lower retaining device 10 by means of the rotary position motor 7 whereby the cylinder 2 can be rotated on the rollers 22 to the desired position without any problems. The first gripper 20 and the second gripper 21 can by means of a slide 23 also be moved towards or away from each other driven by a motor not shown on the Figure.

On Fig. 6 is seen a filling station 6 with measuring equipment in the form of a height adjusting sensor 24, a filler neck positioning unit 25 and in addition a screwgun 26 and a gas filling unit 27 and furthermore a cylinder valve opening/closing unit 28 as seen from above, facing the cylinder 2 and the filler neck 17 of the cylinder.

On Fig. 7 the measuring equipment shown on Fig. 6 appears in the form of a height adjusting sensor 24, a filler neck positioning unit 25 and in addition a screwgun 26 and a gas filling unit 27 and furthermore a cylinder valve opening/closing unit 28 as seen in perspective view. The features indicated on Fig. 7 are further seen in greater detail on Figs. 8 to 11.

On Fig. 8 appears a height adjusting sensor 24 in perspective view; on Fig. 9 is seen a filler neck positioning unit 25 with a measuring unit 29 (here in the form of a measuring finger) in perspective view; on Fig. 10 appears a screwgun 26 for screwing filler adapters 16 in perspective view; and on Fig. 11 is seen a gas filling unit 27 with an overlying cylinder valve opening/closing unit 28 in perspective view.

On Fig. 12 appears a unit on a gas cylinder 2 with i.a. flow regulation 18, protection device 19, flow outlet 30, discharge connection 31, manometer 32 and handwheel shutoff 33.

On Fig. 13 appears a filler adapter 16 with a non-return valve 34 preventing the supplied gas from oozing from the gas cylinder again.

CLAIMS

1. A method for filling gas on gas cylinders with pressures greater than 50 bar in an automatic gas cylinder filling facility, **characterised in** that the method includes at least the following steps:

a. a gas cylinder is placed in a filling carousel;
b. the gas cylinder is positioned by means of a geometric positioning system;
c. a filler adapter is mounted on the gas cylinder;
d. the gas cylinder is filled; and
e. the valve is closed with a certain moment after filling.

2. A method for filling gas on gas cylinders with pressures greater than 50 bar in an automatic gas cylinder filling facility according to claim 1, **characterised in** that the position of the gas cylinder in the filling carousel includes a positioning in the loading station of the filling carousel, where the method step a. further includes at least the following step:

- the gas cylinder is retained at the bottom and at the top by means of retaining devices.

3. A method for filling gas on gas cylinders with pressures greater than 50 bar in an automatic gas cylinder filling facility according to claim 1 or 2, **characterised in** that the gas cylinder is stepped to the first filling station, wherein method step b. further includes at least the following steps:

- a height adjusting sensor detects the height of the gas cylinder, where the height is roughly adjusted by means of motors driving the retaining devices and thereby the gas cylinder up or down, depending on the height detected by the adjusting sensor;
- a measuring unit measures the valve on which the filler neck is located, after which the gas cylinder is rotated by means of a motor to a position at which the filler neck of the gas cylinder is perpendicular to the measuring unit;
- the measuring unit then measures the vertical position of the valve, and the height is fine-adjusted by means of the motors driving the retaining devices and thereby the gas cylinder up or down, depending on the height detected by the measuring unit; and

- the measuring unit measures the horizontal displacement of the valve.

4. A method for filling gas on gas cylinders with pressures greater than 50 bar in an automatic gas cylinder filling facility according to any of claims 1 to 3, **characterised in** that a filler adapter is fitted with screw thread corresponding to the gas in question, wherein method step c. further includes at least the following steps:

- the filler adapter is picked up automatically and screwed on the filler neck of the valve automatically as the position of the valve is completely known and fixed;
- a bushing with an O-ring connection is moved automatically in over the filler adapter and performs a completely pneumatically tight connection; and
- the applied moment is monitored during the screwing on of the filler adapter.

5. A method for filling gas on gas cylinders with pressures greater than 50 bar in an automatic gas cylinder filling facility according to any of claims 1 to 4, **characterised in** that before, during and after method step d. in which the gas cylinder is filled, the method further includes at least one of following steps, which is documented:

- the valve of the cylinder is closed by a given moment;
- the valve is closed and tested for leaks;
- the purity of the gas and the moisture content of the gas is measured.

6. A method for filling gas on gas cylinders with pressures greater than 50 bar in an automatic gas cylinder filling facility according to any of claims 1 to 5, **characterised in** that the gas cylinder is filled, wherein the method after step d. further includes at least one of following steps:

- the cylinder is rotated by means of a motor and an ultrasound device is moved up and down the cylinder, measuring the material thickness;
- the cylinder is rotated by means of a motor and an external inspection of the surface of the cylinder is performed by a 3D camera.

7. An automatic gas cylinder filling facility for filling gas on gas cylinders with pressures greater than 50 bar according to any of claims 1 to 6, **characterised in** that the facility includes a filling carousel with at least one filling station, where the at least

one filling station includes at least one gas cylinder retaining device, a geometric gas cylinder positioning system, a filler adapter and a gas filling unit.

8. An automatic gas cylinder filling facility for filling gas on gas cylinders with pressures greater than 50 bar according to claim 7, **characterised in** that the facility further includes a cylinder placing and removing unit and a loading station.

9. An automatic gas cylinder filling facility for filling gas on gas cylinders with pressures greater than 50 bar according to claim 7 or 8, **characterised in** that the geometrical positioning system at least includes a height adjusting sensor and a filler neck positioning unit with a measuring unit.

10. Use of an automatic gas cylinder filling unit for use in filling gas on gas cylinders with pressures greater than 50 bar according to the method of claims 1 to 6 and the facility according to claims 7 to 9 for filling gas cylinders with medical gases.

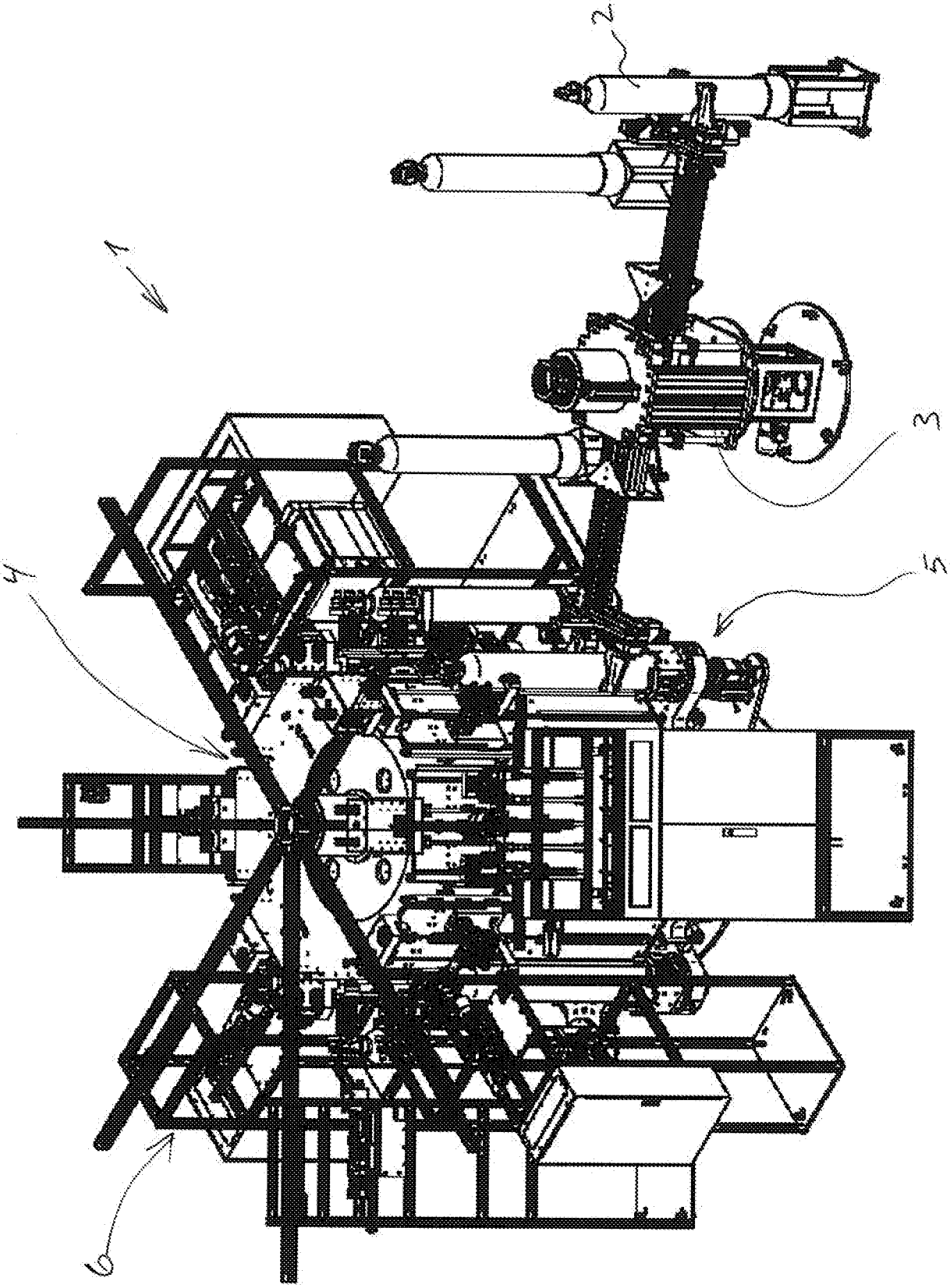


Fig 1

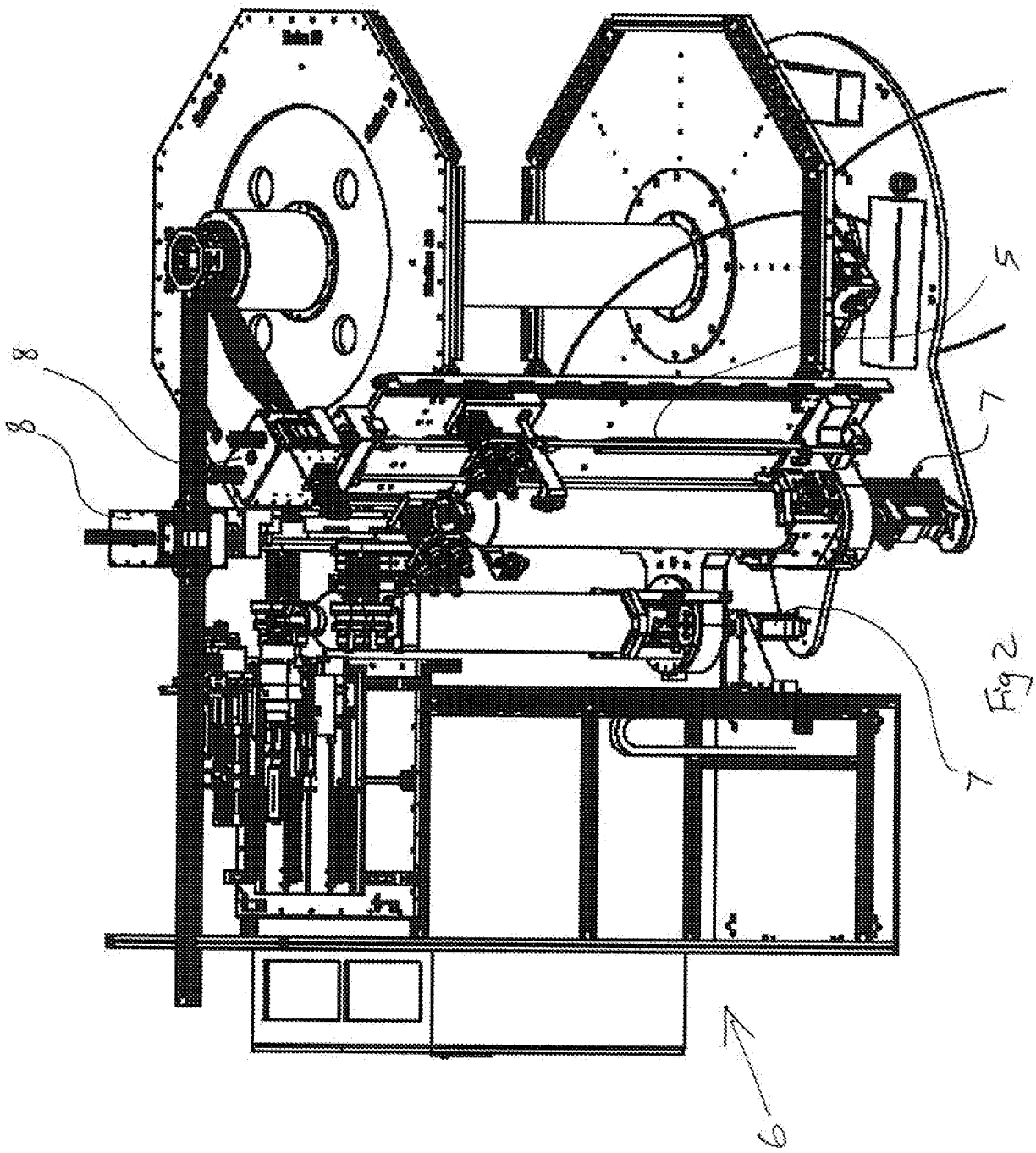


Fig 2

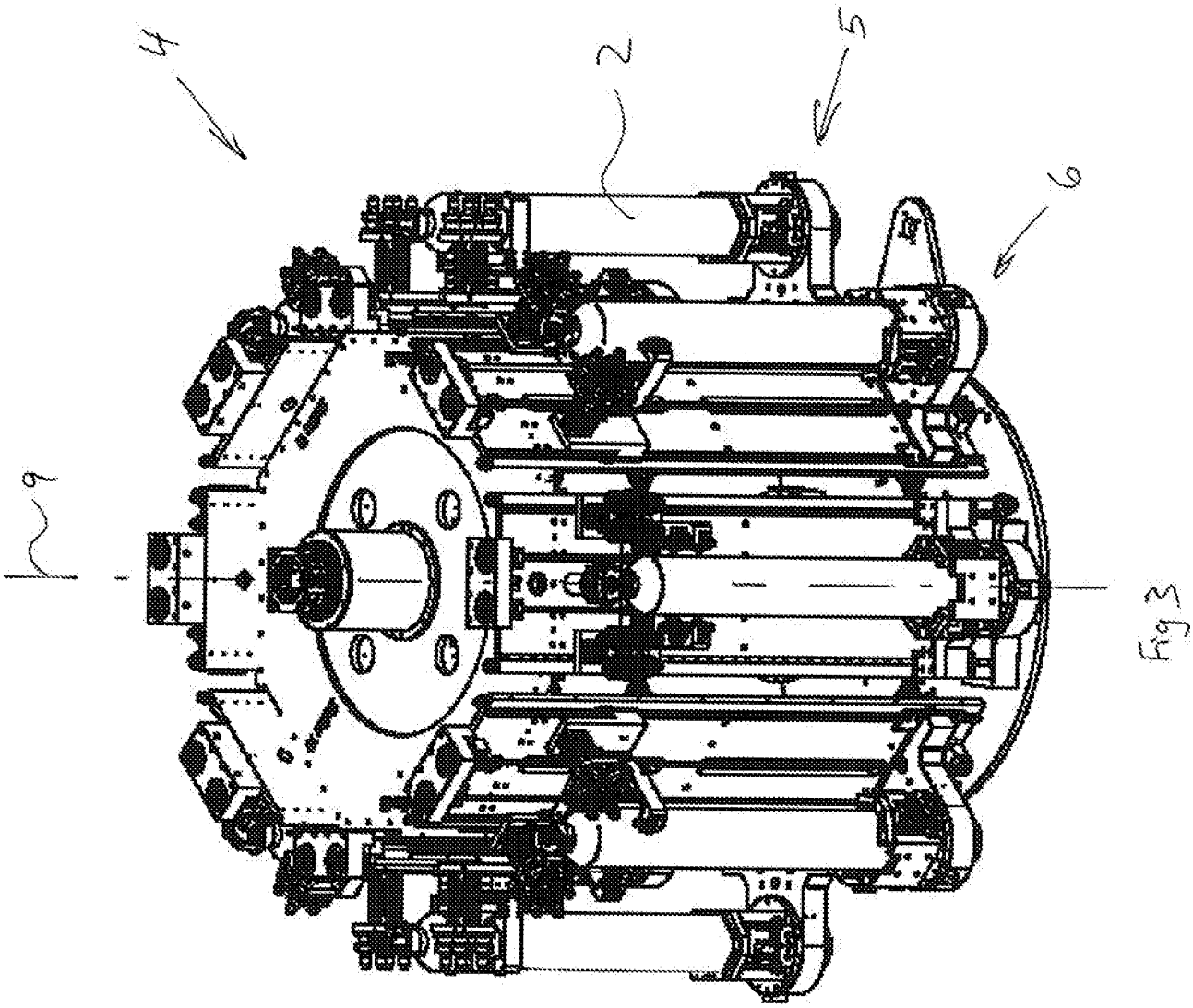


Fig 3

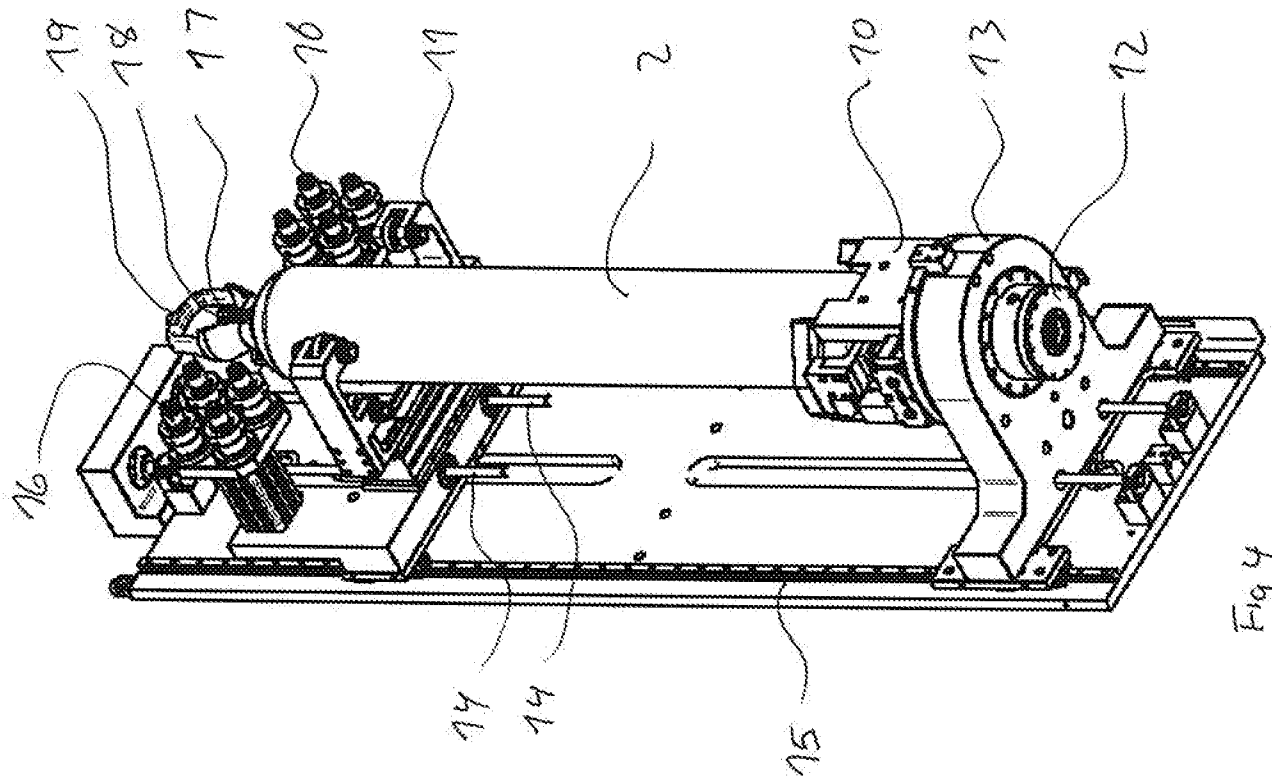


Fig 4

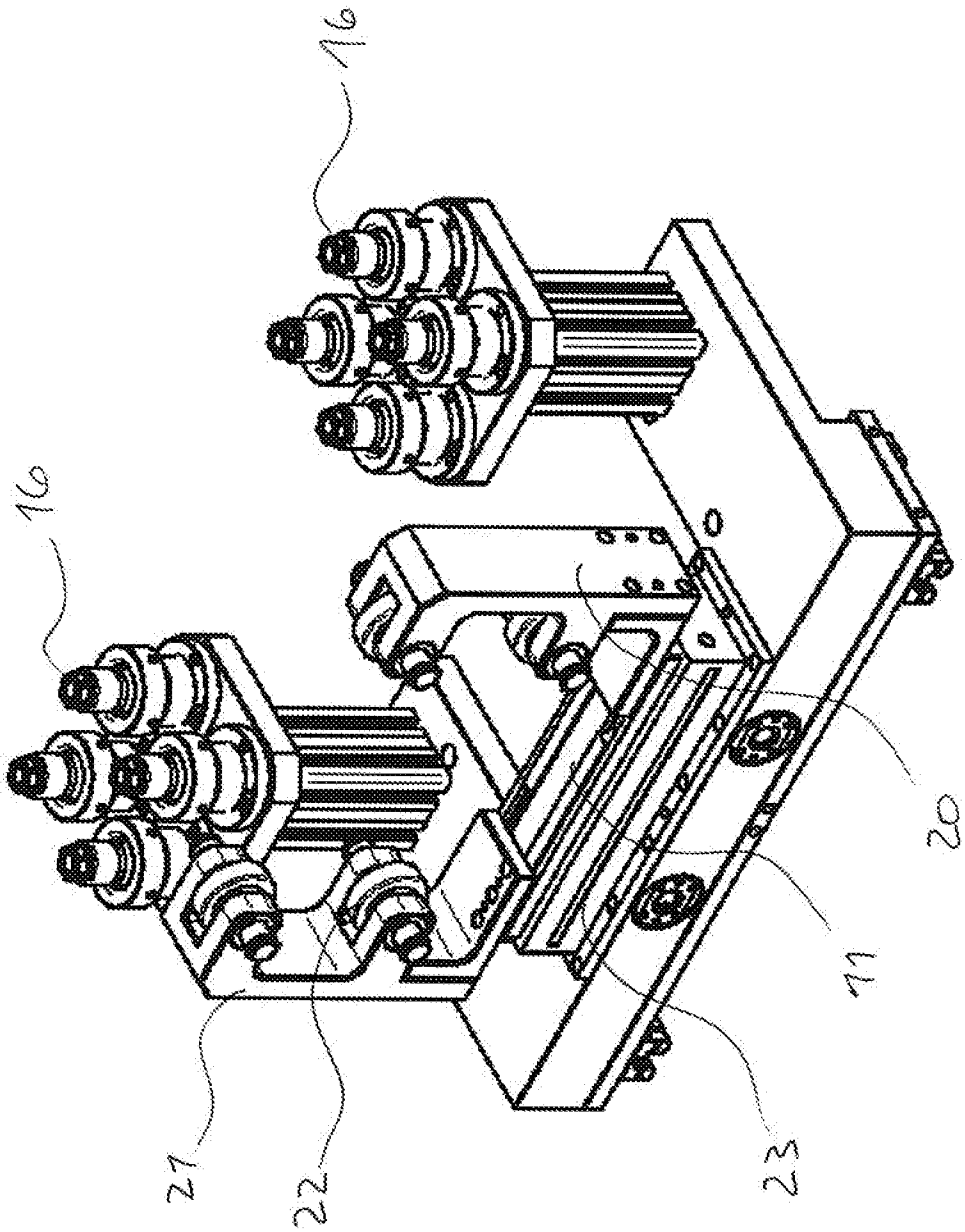


Fig 5

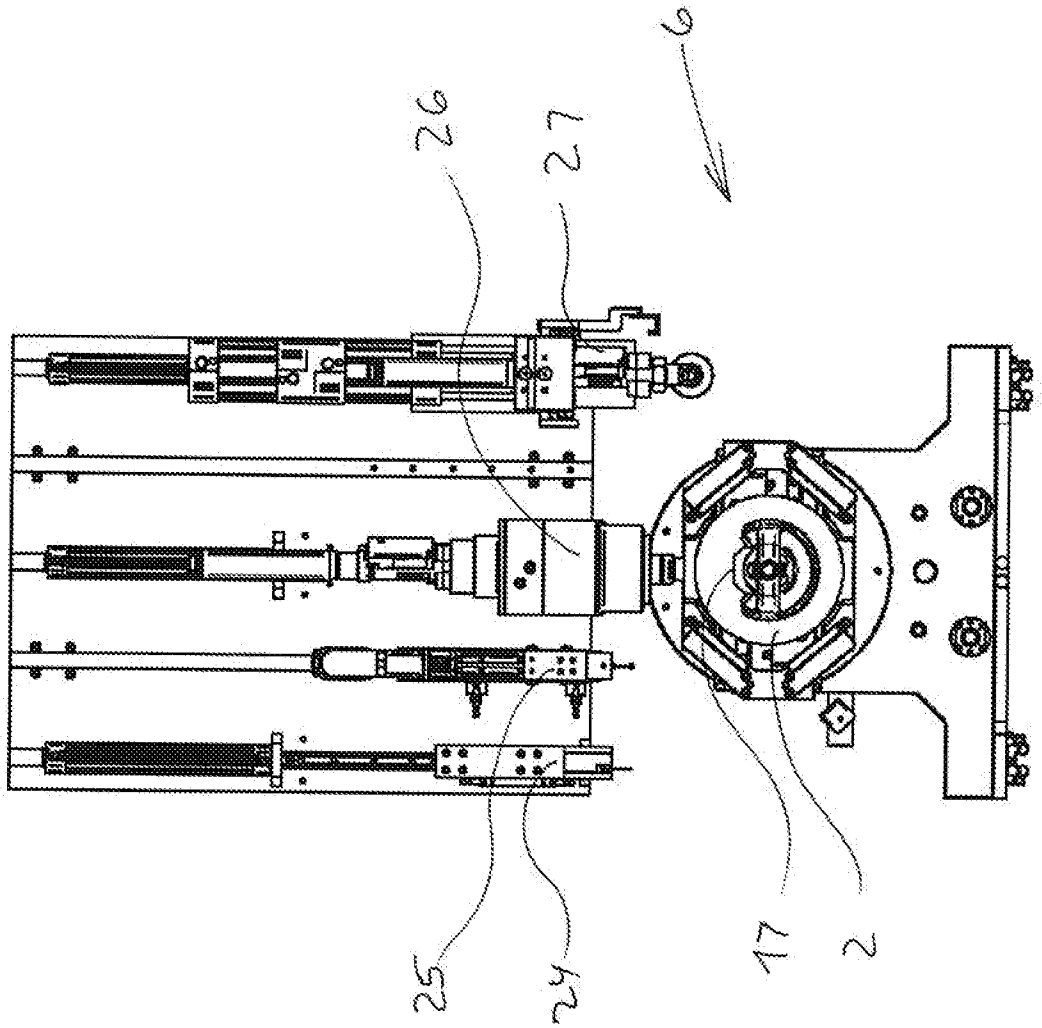


Fig 6

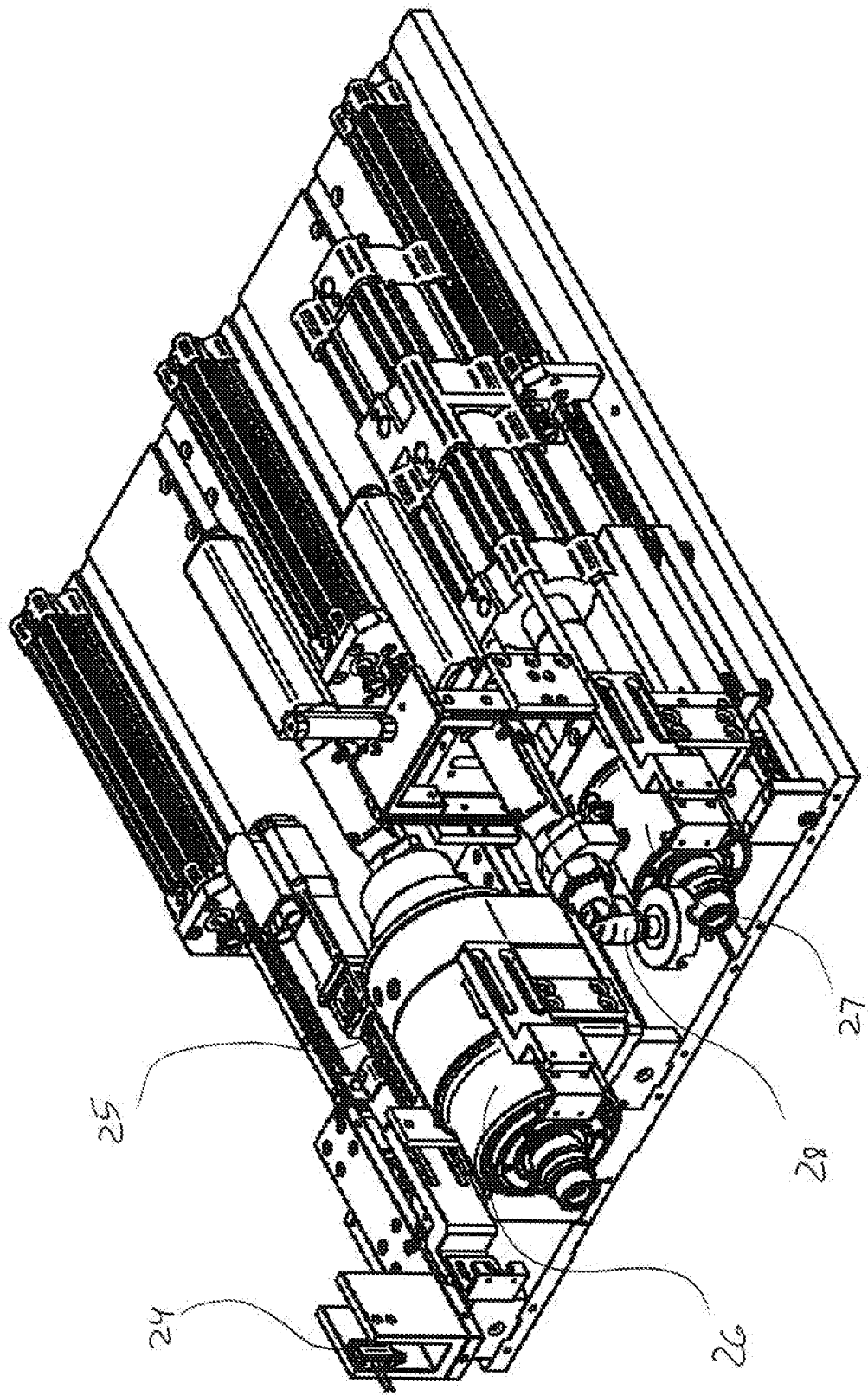


Fig 7

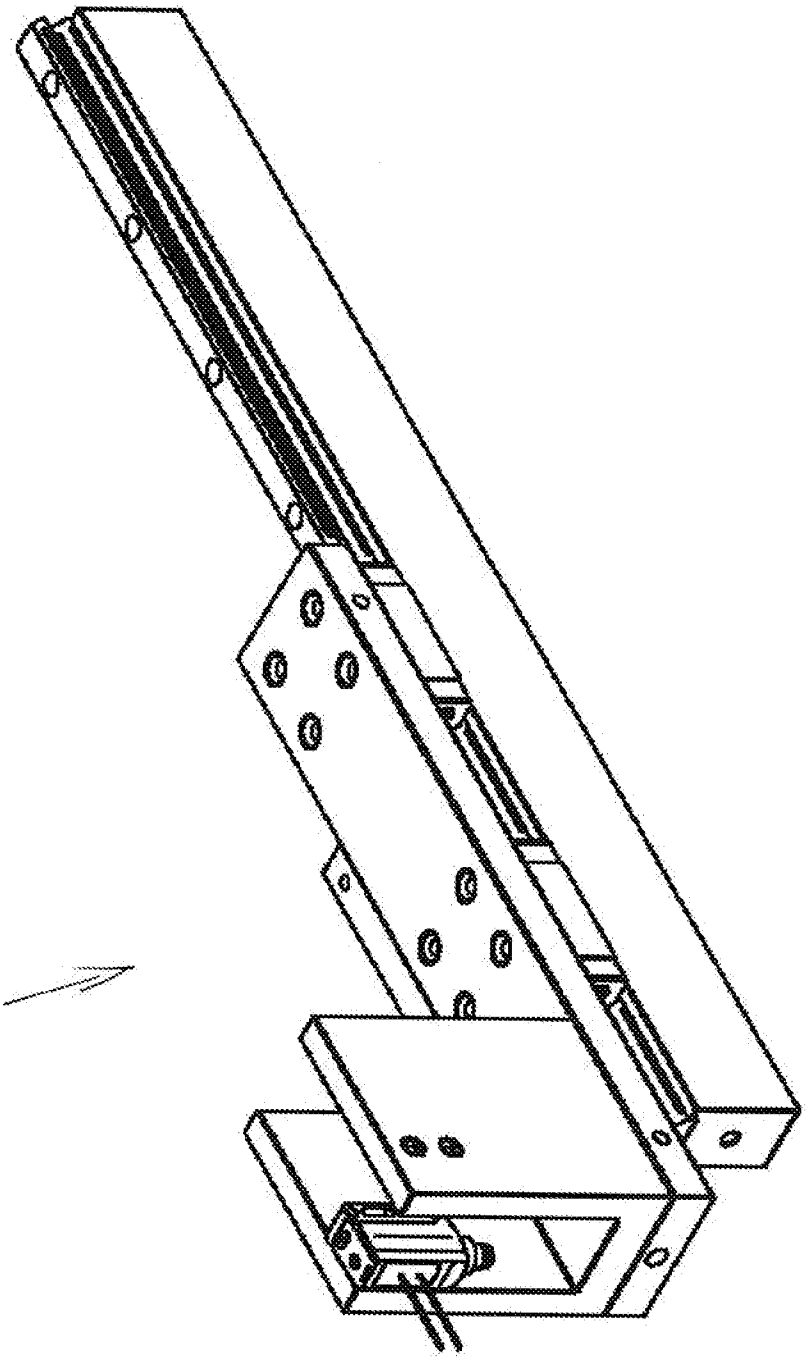


Fig 8

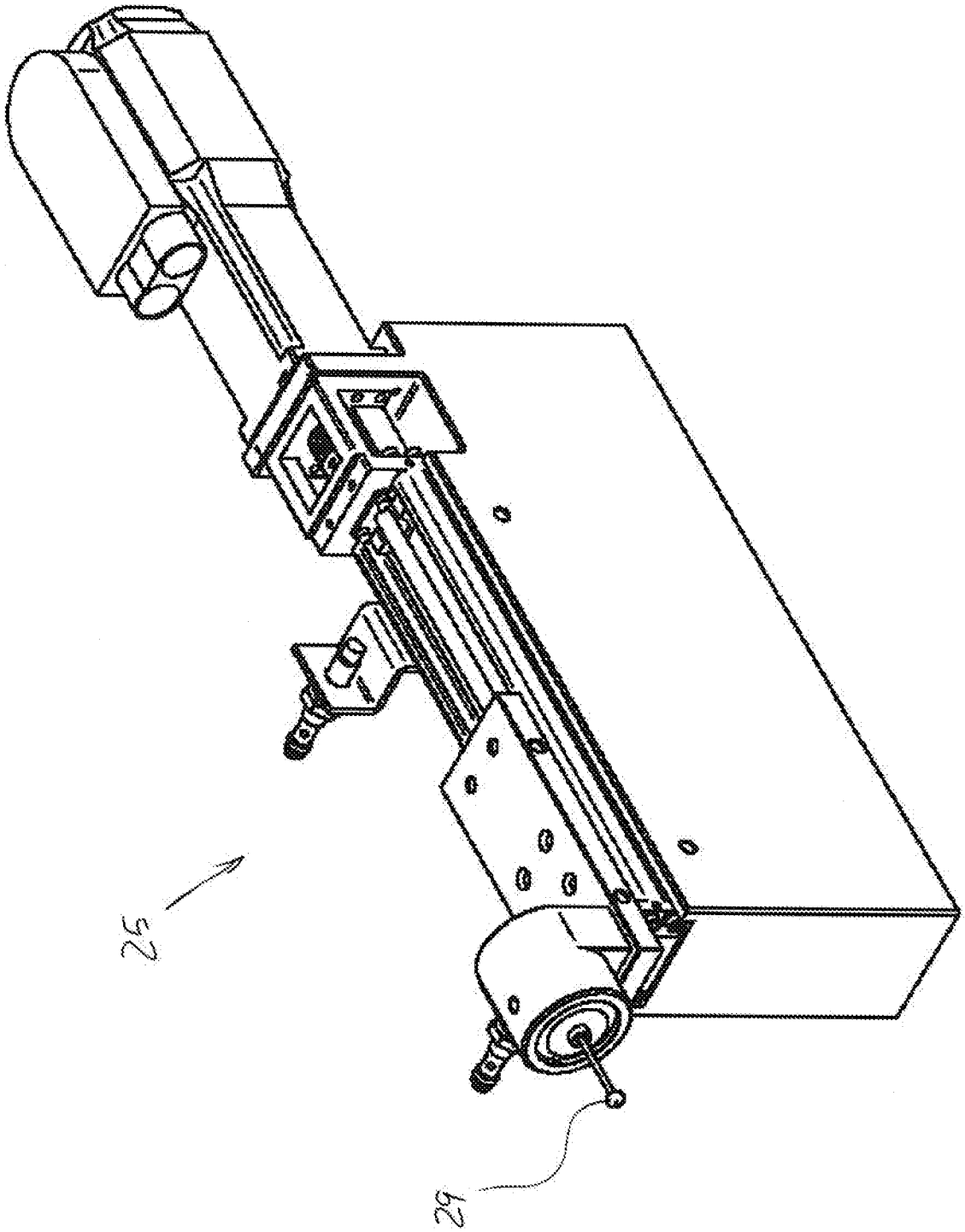


Fig 9

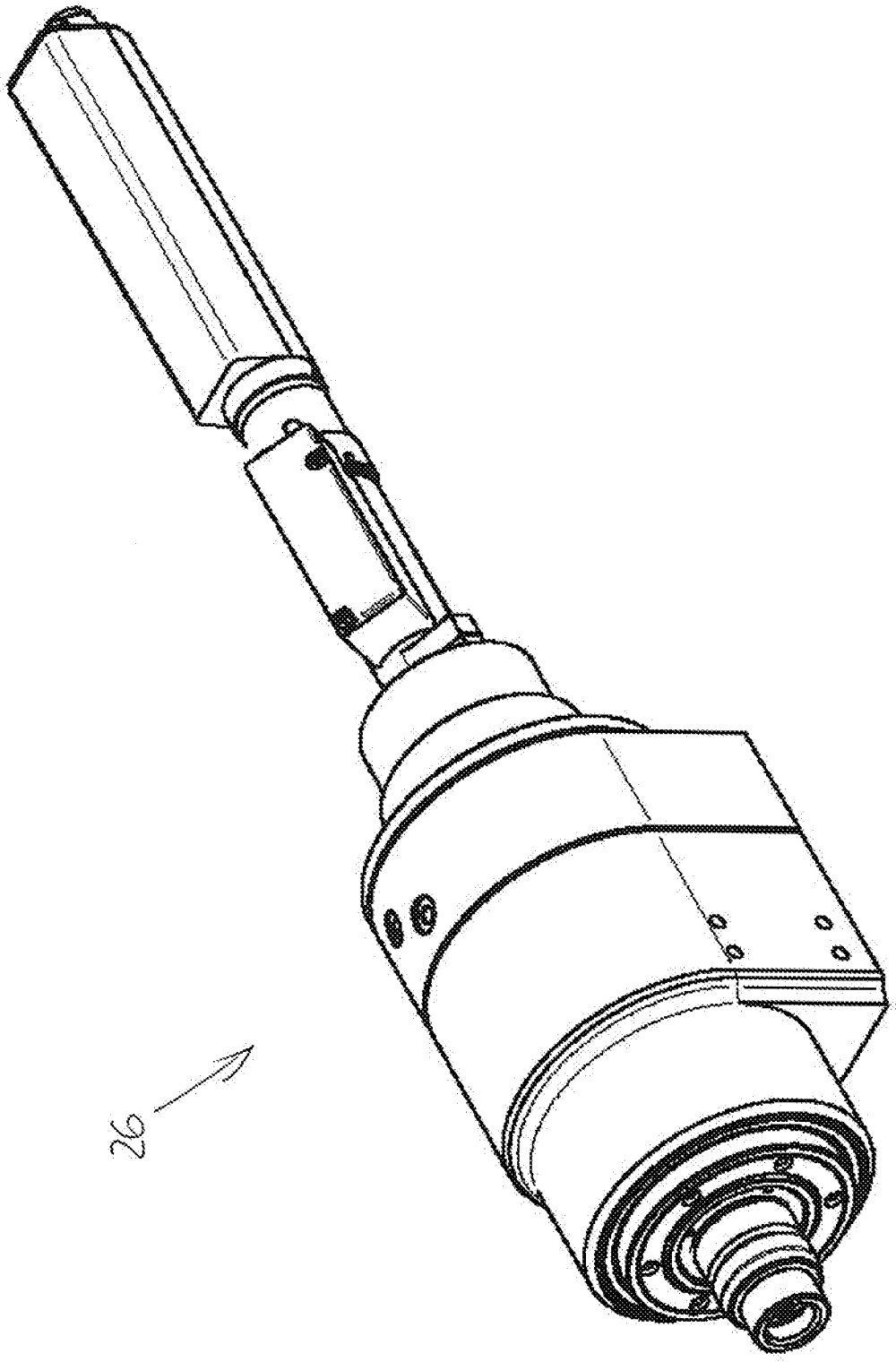


Fig 10

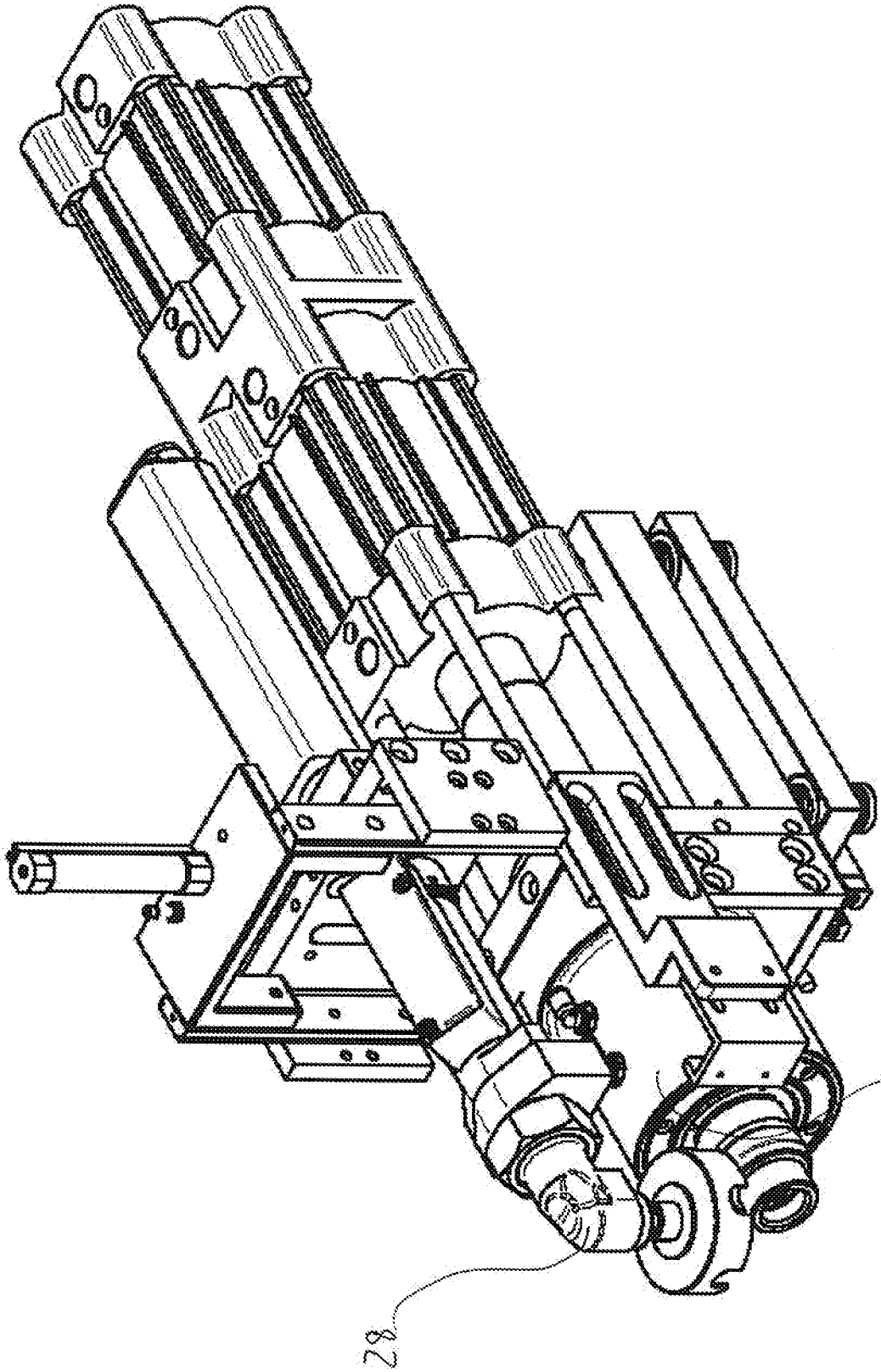


Fig 11

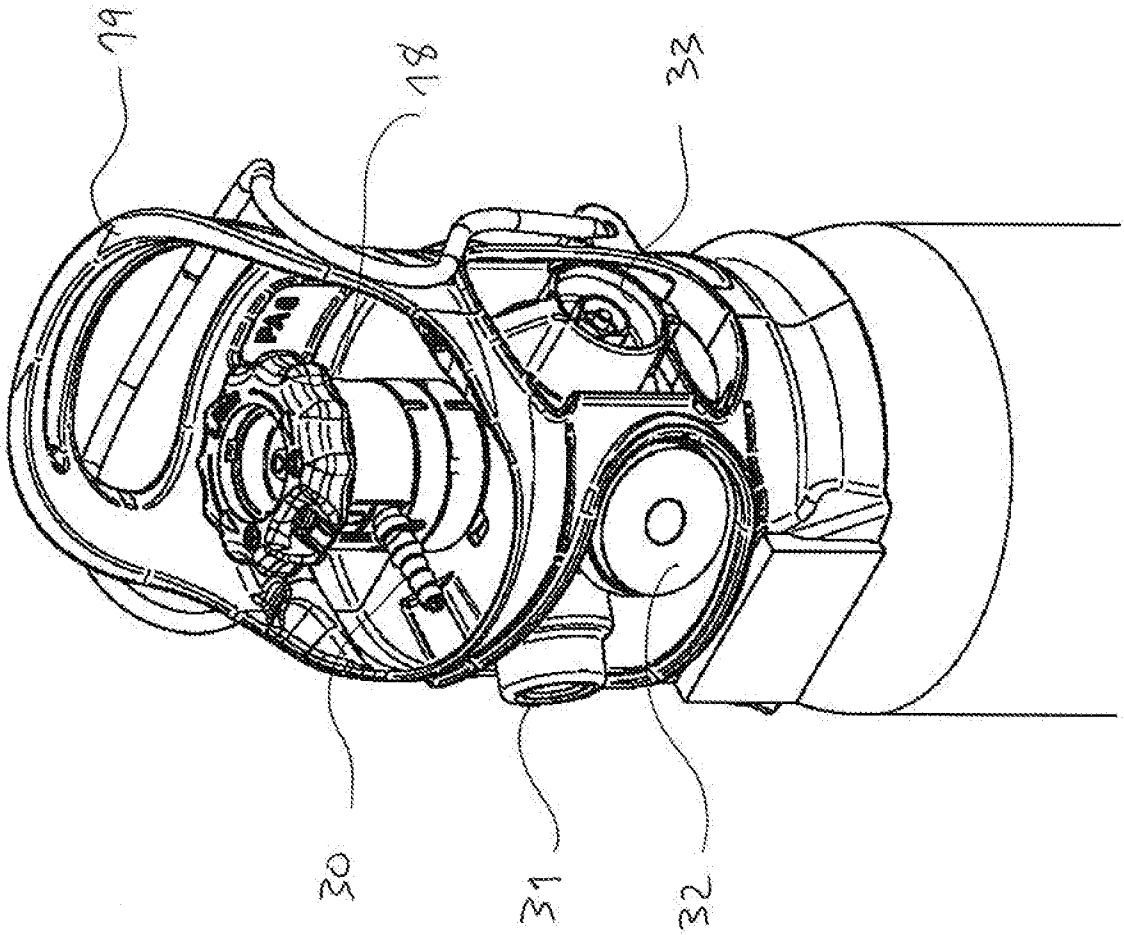


Fig 12

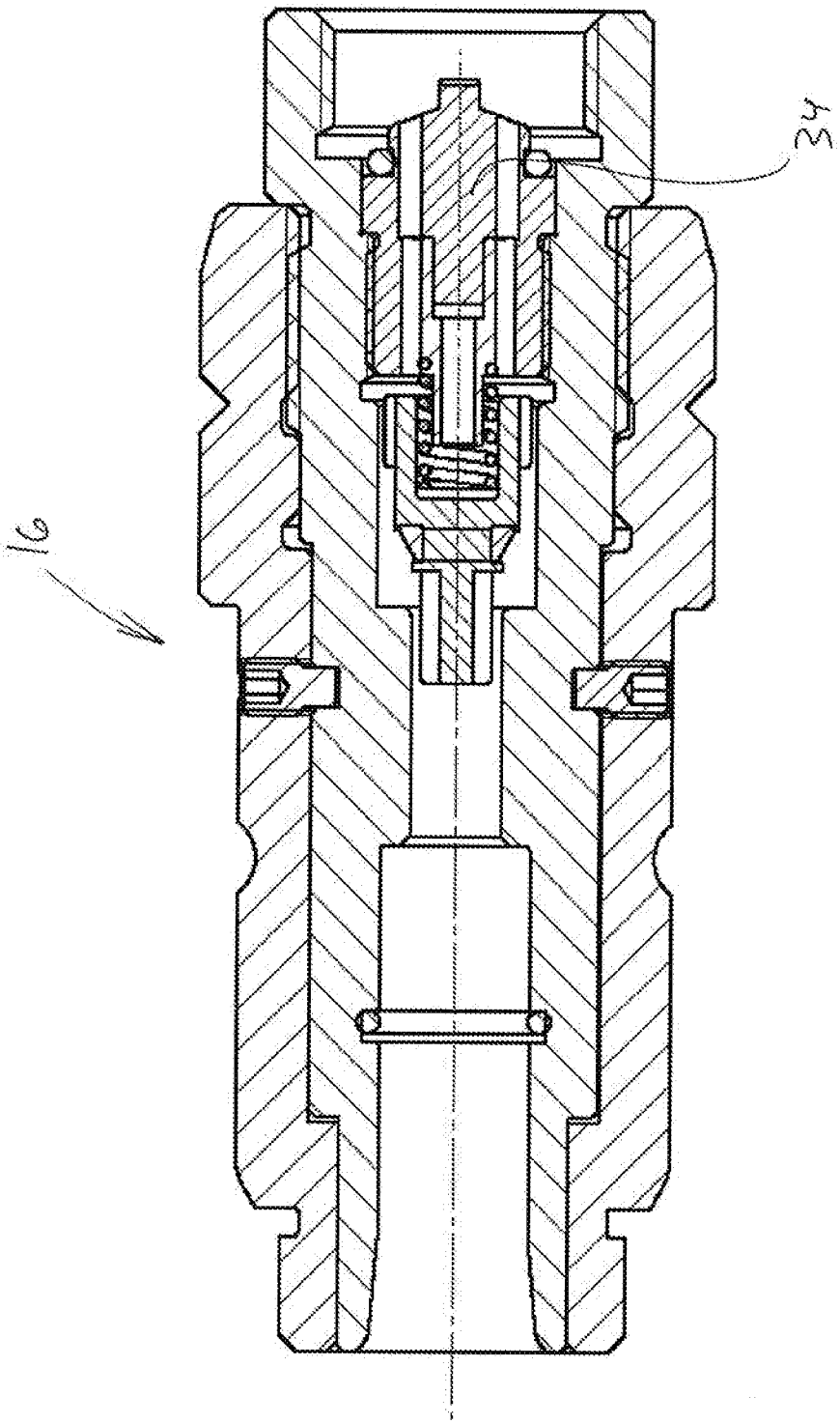


Fig 13

INTERNATIONAL SEARCH REPORT

International application No
PCT/DK2016/050333

A. CLASSIFICATION OF SUBJECT MATTER
INV. F17C5/00
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)
F17C

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, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 23 32 665 A1 (CRISPLANT AS) 17 January 1974 (1974-01-17) fig.1, (2), (38), (40), (42); fig.2, (38), (40), (50); p.6-8; -----	1-10
X	EP 0 537 094 A1 (PAM [FR]) 14 April 1993 (1993-04-14) figs.1-4; fig.1, (1), (30), (21), (25); page 4, columns 5 and 6; p.4, l.25-37 -----	1-10
A	EP 0 617 226 A1 (SIRAGA SA [FR]) 28 September 1994 (1994-09-28) fig.1, (1), (2), (3); claims 1 and 2 -----	1-10
A	EP 0 660 027 A1 (SIRAGA SA [FR]) 28 June 1995 (1995-06-28) fig.1, G1-G12, D1-D12, C1-12; fig.2, B, (1)-(3); abstract -----	1-10

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
11 January 2017	25/01/2017

Name and mailing address of the ISA/	Authorized officer
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INTERNATIONAL SEARCH REPORT

Information on patent family members

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