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Paper A

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<u>Client’s letter</u>

<u>To: Greg Simon, Patent Attorney</u>
<u>Aberdeen, Scotland, UK</u>

Dear Greg,

[001] Wells are channels created in the ground. A typical well includes an outer metal casing which provides structural integrity to the well to stop the surrounding earthen formation from collapsing into the channel created. Many inactive wells are being repurposed as geothermal wells, where hot liquids in the wells power generators to recover renewable energy. However, many wells were created over fifty years ago and a known problem is for small fractures to appear in the metal casing. This can affect a well's integrity, especially if the fracture expands over time, making the well unsuitable for geothermal repurposing.

[002] Using our new device, we would like to deploy a glue onto such fractures to make these old wells suitable for geothermal usage.

[Background]

[003] Devices to deploy acid into a well are known. Such a device D’ is shown in D1 and is illustrated in a well W in a rock formation R, the well W having a metal casing C.

[004] The device D’ has a container 1, separated and sealed by a moveable piston 4 into an acid chamber 2 and a very high pressure gas chamber 3. To deploy the acid from the acid chamber 2 in the well W, a valve 9 is opened and the very high-pressure gas in the chamber 3 drives the piston 4 towards a nozzle 5, thereby expelling the acid from inside the container 1 through the valve 9 and nozzle 5 to outside the container 1 and thus into the well.

[005] However, because of the weight of liquid in a well, pressures inside the well are usually much higher than at the surface. Whereas ambient pressure at the surface is around 1 atmosphere (100 kPa), in a well the pressure gradually increases with depth, and at a common operating depth it can be 10 atmospheres (1 000 kPa). Therefore, the chamber 3 in the container 1 in D1 must be pressurised to a very high pressure (more than 10 atmospheres (1 000 kPa)) to drive the acid out of the container 1, against the high pressure in the well. Handling such pressurised containers at the surface before deployment in a well is very dangerous, because if they collide with other objects at the surface and/or have leaks, they could explode.

<u>[Invention]</u>

[006] We would like to file a patent application for our device which avoids such very high pressures and can be used for deploying glue or other liquids onto a metal casing or elsewhere in a well. Please note, some of our competitors manufacture devices for wells in EU countries where there are no wells. We therefore want our patent application to seek to protect the device *per se*, not just the method of treating a well with the device.

[007] As with Fig. 1a in D1, Figs. 1a and 2 are sectional views of a cylindrical device D, as illustrated by the section X in Fig. 1b. Fig. 1a illustrates our device in an unused glue-containing state. To avoid the high pressure inside the device before deployment, it is provided with a sealed chamber 23 containing gas (usually air) at a pressure that is around 1 atmosphere (100 kPa). This allows for safe handling of the device at the surface. A pressure difference between the higher pressure in the well and the relatively lower pressure in the chamber 23 can drive a moveable piston 14, 15 to expel a liquid, as explained below.

[008] Our container 11 is divided into three sections: a first entry chamber 21, a second chamber 22 for liquid and a third chamber 23 for gas. The moveable piston comprises a piston head 14 and a column 15. The piston head 14 separates and seals the first entry chamber 21 from the second chamber 22 for liquid. The column 15 is attached to the piston head 14 and extends through a static disc 17. The column 15 engages in the static disc 17 and seals it. The static disc 17 separates and seals the second chamber 22 for liquid from the third chamber 23 for gas.

[009] The moveable piston 14, 15 will move if there are unbalanced pressures acting on the upper surface 14U and the lower surface 14L of the piston head 14.

[010] Valves 19 and 29 are necessary to allow or prevent passage of liquid and equalisation of pressure between the outside of the device D and the inside of the first and second chambers 21, 22, respectively. The valve 19 is provided between the inside of the first entry chamber 21 and the outside of the container 11, and the valve 29 is provided between the inside of the second chamber 22 for liquid and the outside of the container 11. A nozzle 35 at the valve 29 is preferably provided to allow the glue or other liquid to be deployed more accurately from the second chamber 22 for liquid.

[011] To use our device, we

(1) seal gas in the third chamber 23 for gas at a given pressure, usually close to 1 atmosphere (100 kPa);

(2) add the deployment liquid to the second chamber 22 for liquid;

(3) deploy the device into a deployment location in the well using a line L;

(4) open the valves 19, 29.

[012] The higher pressure in the well then acts on both sides 14L, 14U of the piston head 14 by way of the glue in chamber 22 and the well fluids in chamber 21. Fig. 1c is an indicative diagram showing the forces acting on the piston head 14 – longer arrows indicating larger pressures. As can be seen from Fig. 1c, the surface area on the lower side 14L of the piston head exposed to well pressure is smaller than the surface area on the upper side 14U of the piston head because of the column 15. The opposite end of the column 15 is instead exposed to the low pressure (compared to the pressure in the well) in the chamber 23. Accordingly, the force urging the piston 14, 15 in the downwards (as drawn) direction is larger than the force urging the piston 14, 15 in an upwards (as drawn) direction. Consequently, when the valves 19, 29 are opened, the net force on the moveable piston 14, 15 is directed downwards (as drawn). The piston head 14 therefore moves down, compressing the chamber 22 for liquid, thus expelling the glue through the nozzle 35 and ending in a glue-expelled state as shown in Fig. 2.

[013] In this way, we can expel glue from our device without requiring a high-pressure container. In preferred embodiments, the pressure in the chamber 23 for gas is the same as the pressure at the surface, 1 atmosphere (100 kPa) +/- 10%, and so it is safe to handle at the surface. The pressure is then relatively low compared to the high pressure in the well, for example 10 atmospheres (1 000 kPa). The exact pressures used are not so important, but in use we do need a pressure difference of at least 5 atmospheres (500 kPa) between the deployment location in the well and the chamber 23 for gas for the device to perform adequately. In our experiments to date, we have found pressure differences of 7 to 9 atmospheres to be optimal for deploying glue. We usually achieve this by the deployment location being deep enough and therefore high enough in pressure (pressure increases with depth), but we can also, to an extent, reduce the pressure in the chamber 23 before deployment.

[014] The orientation of the device is not important. Depending on obstructions in the well, we may deploy the device in an inverted orientation from that illustrated.

[015] Whilst our main focus is to use this device for deploying glue, we would also like to use it for deploying other liquids such as acid. To cope with the well conditions, the container 11 is formed from a metal or metal alloy such as steel.

[016] Our preferred glue is commercially available under the brand name SUBSEA-GLUE™. It consists of:

- bisphenol A epoxy resin (30-60 wt%);
- a sulfone polymer having an average molecular weight of 50 000-100 000 g/mol (30-40 wt%);
- a toughening agent comprising liquid polysulfide rubber (5-15 wt%);
- curing agent comprising amines (5-15 wt%);
- optionally polymer additives.

[017] For the glue a preferred composition can be formulated, e.g.: 40 wt% bisphenol A epoxy resin, 40 wt% sulfone polymer, 10 wt% toughening agent and 10 wt% curing agent.

[018] The sulfone polymer preferably has an average molecular weight of 60 000-90 000 g/mol. We have found that when phenolic antioxidants – a well-known class of polymer additives – are added to the glue, the glue is more resistant to thermal degradation.

[019] The liquid capacity of the second chamber 22 for liquid when the moveable piston is in its starting position, is preferably 5-10 litres. The total volume of the container is preferably 15-50 litres.

[020] To treat a long vertically-extending fracture, we position the device at the top of the fracture, activate it as described above, and then move the device downwards by rolling out more of the line L (alternatively, we could start at the bottom and move upwards by pulling in the line L).

[021] To increase the driving force of the piston, we use a relatively broad column having a diameter of 10 cm, but we expect that a column having a diameter of from 5 to 15 cm would work well.

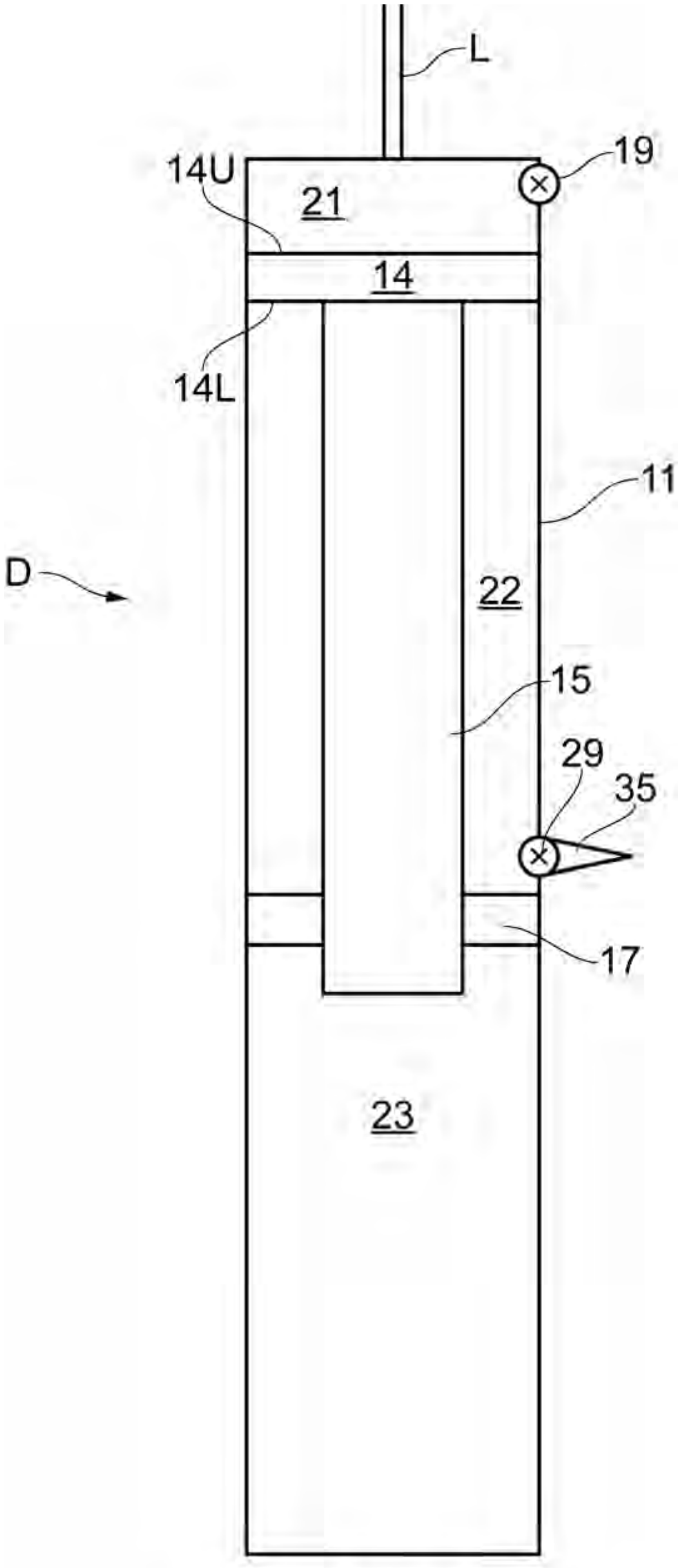
[022] I attach here an extract from a glossary (D1 as described above) and D2, which we found during a patent search.

[023] Note, the SI unit for pressure is pascals, not atmospheres. We have indicated the pressure in kilopascals (kPa) above. Also, the average molecular weight of the sulfone polymer mentioned above is a *weight* average molecular weight. However, it is not to be confused with the *number* average molecular weight, which is a different metric. Depending on the method of measurement, the measured values can vary greatly. In our experiments, the weight average molecular weight was measured by light scattering according to the standard method ASTM D4001-20.

[024] Please draft a set of claims and an introductory part of the description for a European patent application to protect our invention. It should be assumed that the drawings accompanying this letter will form part of the application. Unfortunately, we have no financial budget for claims fees or for further patent applications.

Best regards,
Anna Watt

<u>Client’s drawings</u>



(Invention)
FIG. 1a

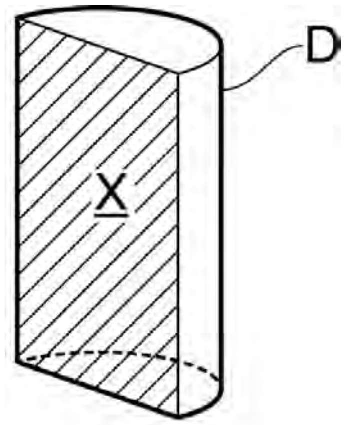


FIG. 1b

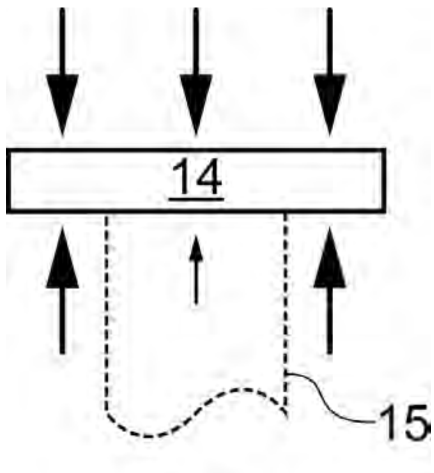
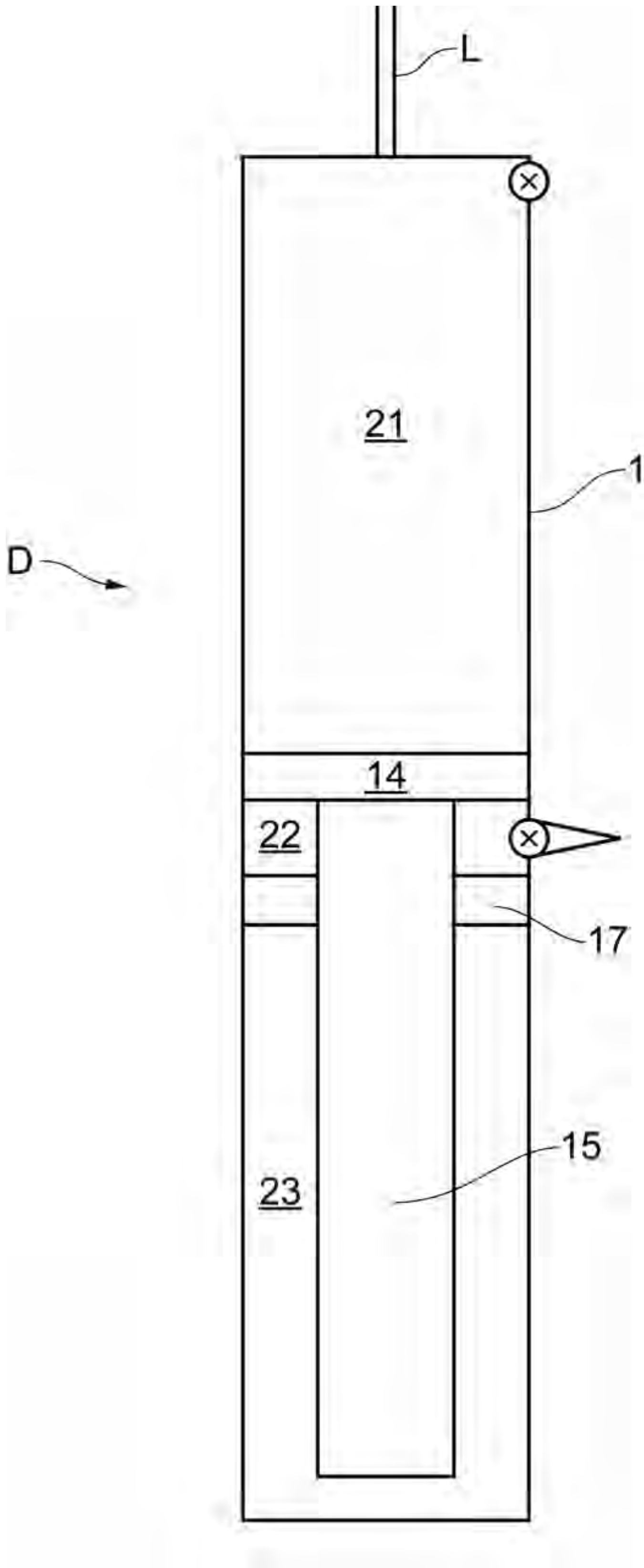


FIG. 1c



(Invention)
FIG. 2

Prior art D1

Extract from oilfield glossary

Acid treatment

[001] Acid treatment of wells can be used to remove debris that is inhibiting flow of fluids in the well. A pressurised container is deployed downhole and drives a piston to deploy acid into the well. See Figs. 1a and 1b, which show a device D’ in a well W in a rock formation R, the well W having a metal casing C.

[002] The device D’ is cylindrical in shape, as shown in Fig. 1b. Fig. 1a shows the section X taken through the cylinder-shaped device D’. The device D’ has a container 1, separated and sealed by a moveable piston 4 into an acid chamber 2 and a very high-pressure gas chamber 3. When it is required to deploy the acid from the chamber 2 into the well W, a valve 9 is opened and the very high-pressure gas in the chamber 3 drives the piston head 4 towards a nozzle 5, thereby expelling the acid from inside the container 1 through the valve 9 and nozzle 5 to outside the container 1 and thus into the well. The device may be used to remove solids blocking flow paths in the well.

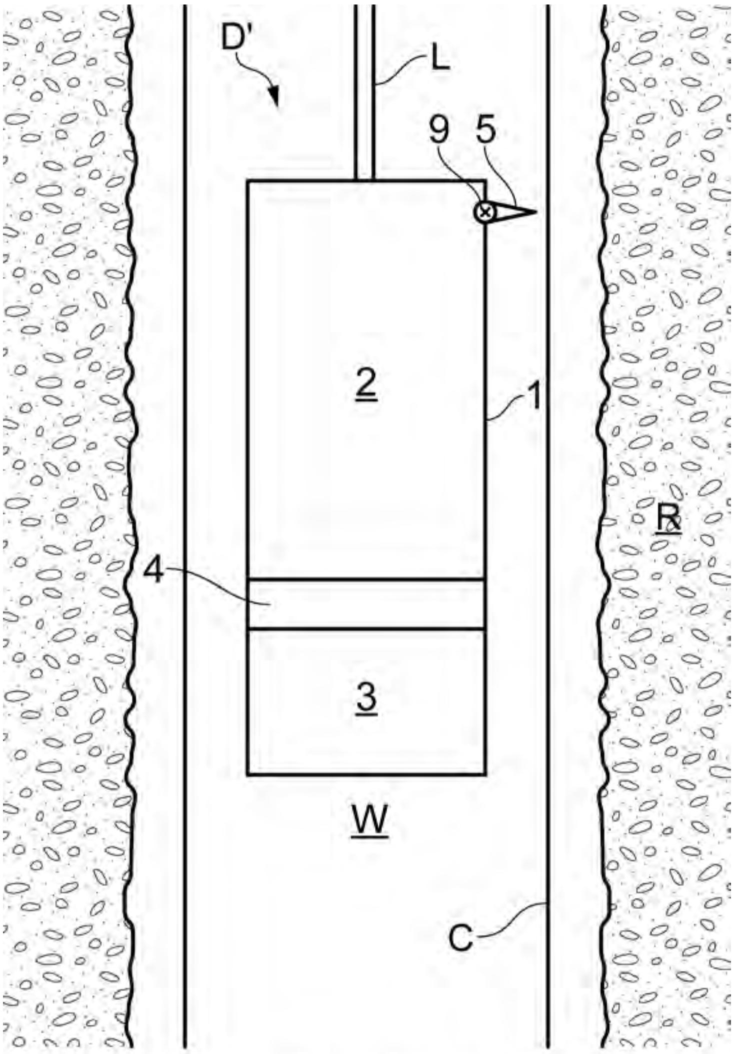


FIG. 1a (Prior Art)

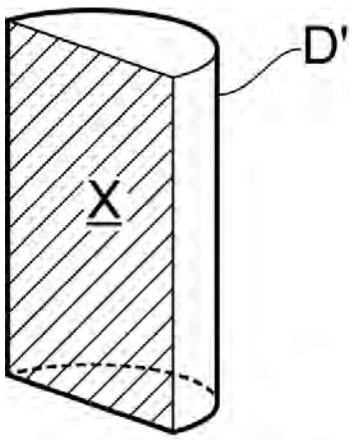


FIG. 1b

<u>D2 Description</u>

[001] Fig. 1a is a turbine apparatus to generate electricity in a well. Data transmitters in a well require power. Whilst batteries can be used, the high temperatures often found in wells cause them to deteriorate quickly. Instead, we propose a turbine device D'' in the form of a cylindrical container 101 having a first drive chamber 121, a second liquid chamber 122 and a third low-pressure chamber 123 for gas. The drive chamber 121 is open to the surrounding well via an opening 119 which can be any size.

[002] A piston 114, 115 moves in the container 101, depending on the relative pressures acting on it. The piston head 114 delineates the drive chamber 121 from the liquid-containing chamber 122 and seals them from each other.

[003] A static disc 117 generally delineates the second liquid chamber 122 from the third low-pressure chamber 123, but includes a neck 142 with a valve 143 which connects the second liquid chamber 122 and the third low-pressure chamber 123 for gas when the valve 143 is open and seals them from each other when the valve 143 is closed. The neck 142 also includes a turbine 141 with turbine blades.

[004] Before deployment, we evacuate the low-pressure chamber so that it is at 0.5 times atmosphere pressure (50 kPa). To be worthwhile, the pressure in the well at the depth of deployment should be at least 8 times atmospheric pressure (800 kPa).

[005] When power is required the valve 143 is opened, and the high pressure in the well, compared to the much lower pressure in the low-pressure chamber 123 for gas, drives the piston 114 down and drives the fluid through the turbine 141 and the valve 143. The consequential turbine rotation generates power, which can be stored by a capacitor 146 and used as required by a transmitter 145 to send signals back to the surface.

[006] The piston 114, 115 continues down towards the turbine 141 until a mechanical override in the form of a rod 115 then extends between the turbine blades to stop them turning and to prevent discharge of the capacitor 146 back into the turbine 141. The rod 115 then extends through the valve 143 into the low-pressure chamber 123 for gas to ensure it remains open as the apparatus is subsequently removed from the well. Fig. 1b shows the rod 115 between the blades of the turbine 141 in the neck 142. The piston head 114 eventually abuts the neck, as shown in Fig. 1b. The rod needs to be less than 7 cm in diameter to fit through the valve and between the turbine blades.

[007] The apparatus is then spent and can produce no more power. It can be recovered to the surface. When spent, the apparatus may still contain fluids at a similar high pressure to the conditions in which it operated in the well. As the apparatus is recovered to the surface, the pressure in the well at shallower depths is reduced and is even lower at the surface. Handling high-pressure containers at the surface is dangerous. Therefore, during transit out of the well, a valve 129 can be opened to allow fluids to be expelled from the container and reduce the pressure inside as it passes through lower-pressure/shallower parts of the well. The loose fitting of the rod 115 in the neck 142 ensures the former low-pressure chamber 123 for gas can also depressurise in this way, past the valve 143 and turbine 141 in the neck 142.

[008] The liquid used in the liquid chamber 122 can be oil, water, brine or acid.

[009] In an alternative embodiment, a control valve may be provided instead of the opening 119 to control ingress of fluid into the drive chamber 121.

[010] The turbine apparatus can be used in different wells, such as production wells, injection wells or geothermal wells.

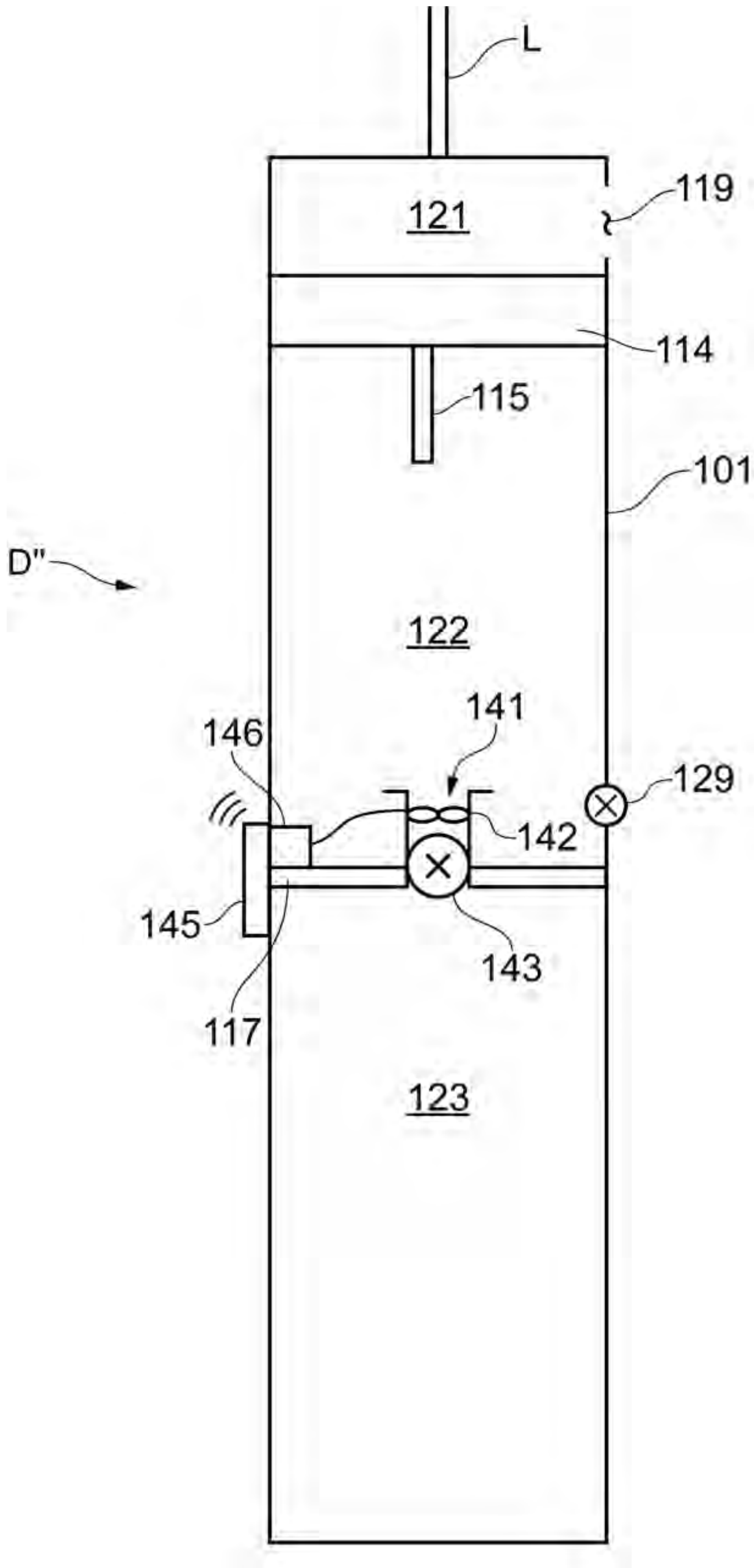


FIG. 1a

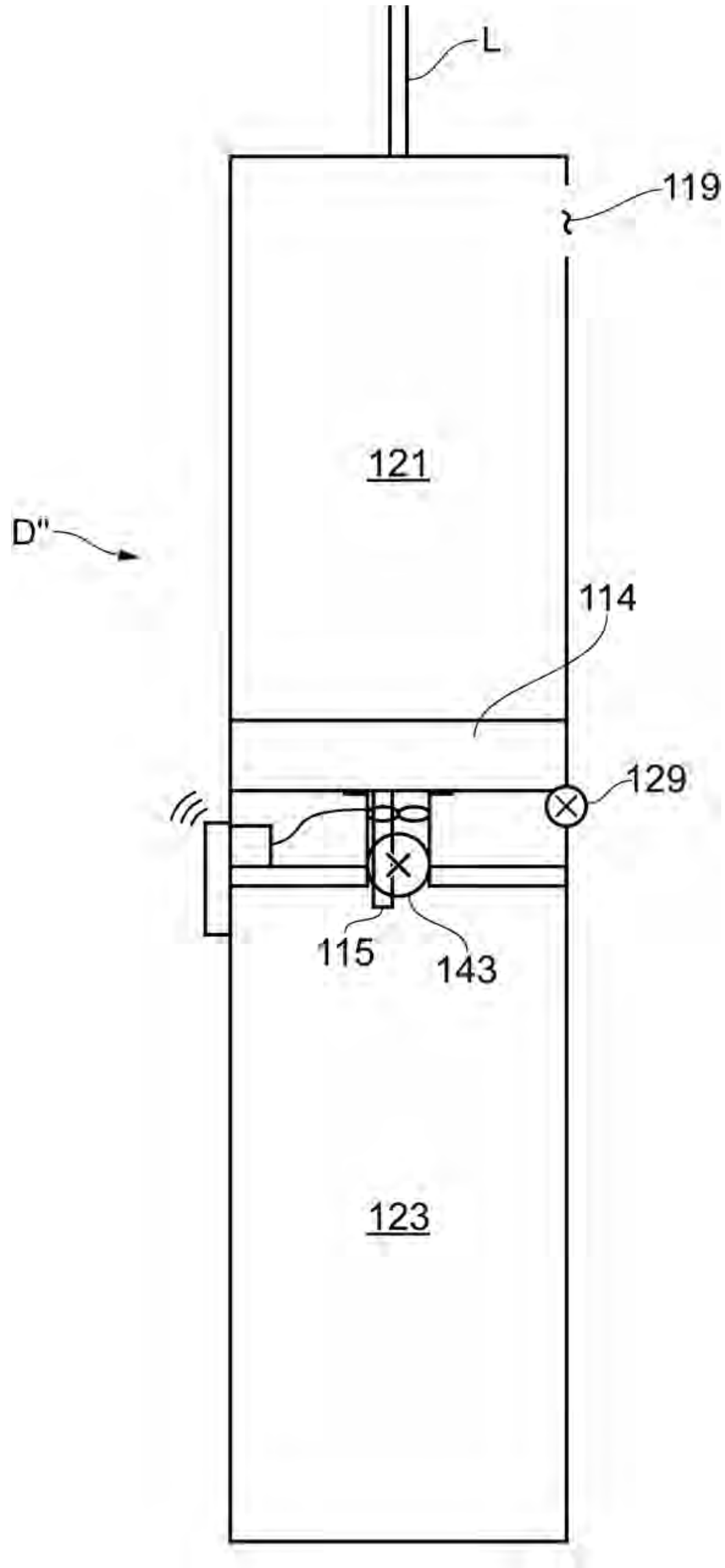


FIG. 1b