



(11) **EP 2 492 437 B1**

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention of the grant of the patent:  
**09.12.2015 Bulletin 2015/50**

(51) Int Cl.:  
**E21B 23/00<sup>(2006.01)</sup> E21B 34/14<sup>(2006.01)</sup>**

(21) Application number: **12157150.9**

(22) Date of filing: **27.02.2012**

(54) **Activation device for use in a downhole well**

Aktivierungsvorrichtung zur Verwendung in einem Bohrloch

Dispositif d'activation pour une utilisation dans un puits de forage

(84) Designated Contracting States:  
**AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR**

(30) Priority: **25.02.2011 GB 201103295**

(43) Date of publication of application:  
**29.08.2012 Bulletin 2012/35**

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## Description

**[0001]** The present invention relates to an activation device such as an activation ball for controlling the operation of a downhole tool, particularly for use in an oil or gas well. Many different kinds of downhole tool are known to be controlled using activation balls; typical examples are tools used in drill strings and/or tools used in production strings used to transport production fluids through the borehole.

**[0002]** Known activation balls are normally substantially spherical and are dropped into the wellbore from an insertion point at the surface and travel through the wellbore to the downhole tool. The activation ball may be carried by drilling mud or another fluid that is pumped through the wellbore. The fluid may be contained in a wellbore tubular or another structure of the wellbore.

**[0003]** When the activation ball reaches the downhole tool the ball lands on a seat of the downhole tool allowing fluid and/or hydraulic pressure to be applied to the ball on the seat. The fluid pressure is generally applied from the surface and the force resulting from the pressure is used to operate the downhole tool, typically by moving the ball and the seat, or some mechanism connected to it to change the activation status of the downhole tool, for example to activate or de-activate it.

**[0004]** It is known to use a deformable activation ball or deformable seat that deforms under increased fluid pressure such that the ball is forced past the seat and out of the downhole tool when the hydraulic pressure is increased beyond a threshold. This has the advantage that a succession of activation balls can be sent downhole from the surface to activate and deactivate a downhole tool.

**[0005]** US3339647A discloses a method for expanding cutters on a rotary drilling bit in a well bore by sending an erodible ball made of mild steel down into the drill pipe to rest upon, and eventually pass through, a valve seat.

**[0006]** Deformable activation balls and a deformable seat on the downhole tool address the problem of how to activate and then deactivate or reactivate a downhole tool. Previously if the first activation ball sent downhole did not activate the downhole tool, then often the downhole tool and associated equipment would have to be raised back to surface so that the activation ball could be retrieved, before the tool was lowered downhole once more.

**[0007]** Deformable activation balls and seats however have significant design problems. They require very precise manufacturing tolerances to provide adequate resistance to increased fluid pressure acting on the ball and therefore facilitate operation of the downhole tool, whilst retaining the required amount of deformability to allow the ball to be forced past the seat and out of the downhole tool at the required higher pressure.

**[0008]** According to a first aspect of the present invention there is provided an activation device for use in a downhole well for activation of a downhole tool in the

well, the downhole tool having a seat adapted to engage the activation device whereby engagement of the activation device in the seat changes the activation status of the downhole tool, the activation device being adapted for passage through the borehole of the well and being adapted to engage the seat of the downhole tool in the well to change the activation status of the downhole tool, characterised in that: the activation device comprises an outer layer and a core housed within the outer layer, wherein the core comprises a material that is more susceptible to erosion than the material of the outer layer; and wherein the material of the outer layer is adapted to resist erosion during passage of the activation device through the borehole of the well in normal operating conditions, and wherein the material of the outer layer and the core are adapted to be eroded by drilling fluid when the activation device is engaged in the seat in the downhole tool, whereby the drilling fluid erodes the seated activation device such that the activation device is able to pass through the seat.

**[0009]** The activation device may comprise a substantially spherical ball or may be cylindrical in shape. The seat of most downhole tools is adapted to receive a substantially spherical ball. A spherical activation device obviates the need to control the orientation of the activation device relative to the seat and/or tool and therefore optimises contact between the ball and the seat. The activation device may be a drop ball.

**[0010]** The core may have a compressive strength from 10 to 140MPa. Optionally the core has a compressive strength of between 60 and 100MPa. Optionally the core has a compressive strength of between 70 and 90MPa. The core may have a compressive strength of 80MPa. The core may provide structural strength to the activation device. The core can provide the required structural strength if the compressive strength of the core is sufficient to withstand impact of the activation device against the sides of the borehole during passage of the activation device through the borehole of the well, the impact of the activation device on the seat and the force applied to the activation device through the drilling fluid to activate the downhole tool. The core may have a compressive strength such that the shape and size of the activation device remain substantially constant at least during passage of the activation device through the borehole of the well and change of the activation status of the downhole tool.

**[0011]** The material of the outer layer may be one or more of cement; concrete; epoxy resin; ceramic; and MO-LYKOTE<sup>(RTM)</sup> as supplied by Dow Corning Corporation. The outer layer may be a protective layer that surrounds the core and protects the core from erosion by the drilling fluid until the activation device is on the seat. The outer layer may be resistant to dissolution in the drilling fluid, and may form a barrier between the drilling fluid and the core, preventing access to the core by the drilling fluid until erosion of the outer layer when the activation device is seated.

**[0012]** The material of the core may be one or more of wax; salt; and sand. The core may be more susceptible to erosion by the drilling fluid than the outer layer. This may reduce the time taken for the activation device, including the outer layer and core, to be eroded and subsequently pass through the seat, thereby clearing the downhole tool for further unimpeded operation of the downhole tool or a further change in the activation status of the downhole tool to be affected by a second activation device. The outer layer may therefore remain intact until the activation status of the downhole tool has been changed.

**[0013]** The compressive strength of the salt core may be between 20 and 60 MPa. The compressive strength of the epoxy outer layer may be between 80 and 120 MPa. The compressive strength of the concrete outer layer may be between 80 and 100 MPa.

**[0014]** The core may have a coating disposed between the core and the outer layer, the coating comprising a wax. The coating may provide a barrier that separates the core from the outer layer, and may reduce or prevent contact of the outer layer by the core material. Such contact may for example prevent the outer layer from forming during manufacture of the activation device and/or cause premature degradation of the outer layer.

**[0015]** The activation device may be adapted to be eroded by the flow of drilling fluid when the activation device is located in the seat. When located in the seat, the activation device may reduce the available flow path past the seat, but normally does not close the flow path past the seat entirely, and normally the flow of drilling fluid past the activation device may be possible because the seat has slots, apertures or other suitable forms of bypass channels that always remain open.

**[0016]** The core may comprise a material adapted to change state from solid to liquid when exposed to normal temperatures in the environment of the seat. The core may comprise a wax. The compressive strength of the activation device may be reduced when the wax has melted and is in liquid form. This may help to promote fragmentation of the activation device after it has engaged the seat and the activation status of the downhole tool has been changed.

**[0017]** The core may comprise an inner core and an outer core. If the activation device has more than one core then the compressive strength of the core can be adapted and varied to suit a particular application. A crust on the activation device may also be used to adapt the overall compressive strength of the activation device. There may be one or more layers between the core and the outer layer, these one or more layers may also be used to adapt the overall compressive strength of the activation device.

**[0018]** The activation device may have an external or outer diameter of between 10 and 100mm; optionally between 30 and 70mm; and normally 54mm. These external or outer diameters mean that the activation device is small enough to pass through the borehole of a downhole

well and big enough to engage with a typical seat of a typical downhole tool to activate and/or deactivate the tool.

**[0019]** The core may have a diameter of between 9 and 99mm; optionally between 29 and 69mm; and normally between 52 and 53mm. These core dimensions are normally sufficient to provide the activation device with an outer layer of sufficient thickness to provide the resistance to erosion by the drilling fluid the activation device requires before and/or during passage of the activation device through the borehole of the well to the downhole tool.

**[0020]** According to a second aspect of the present invention there is provided a method of operating a downhole tool in a borehole of an oil or gas well, the downhole tool having a seat for engaging an activation device, the method comprising the steps of:

providing an activation device adapted to pass through at least a part of the borehole and engage the seat, the activation device comprising a core and an outer layer of material housing the core; wherein the core comprises a material that is more susceptible to erosion than the material of the outer layer, whereby erosion of the outer layer to expose the core takes more time than the subsequent erosion of the core;

transporting the activation device in a flow of drilling fluid through the borehole from an insertion point in the borehole to the seat of the downhole tool, whereby the activation device engages in the seat of the downhole tool; changing the state of activation of the downhole tool when the activation device engages with the seat, and eroding at least a portion of the activation device with drilling fluid until the activation device can pass through the seat.

**[0021]** The downhole tool can be activated and then deactivated or reactivated using two or more activation devices of substantially the same external dimensions. Using the method of the second aspect of the present invention negates the need to use objects of increasing size or increasing external dimensions to subsequently deactivate or reactivate the downhole tool. The activation device of the present invention is particularly suited for repeatedly operating a downhole tool.

**[0022]** Adapted to erode means the materials of the core and outer layer can one or more of wear away; partially disintegrate; disintegrate; deteriorate; and decay. The step of eroding the activation device may include the steps of eroding the material of the outer layer and then subsequently eroding the material of the core.

**[0023]** The outer layer may be eroded by the action of the downhole fluid in contact with the activation device. The activation device may be eroded by flowing the drilling fluid past the activation device when the activation device is in the seat of the downhole tool. This means that the activation device can be added to the borehole,

pass through at least a part of the borehole and engage the seat of the downhole tool, change the state of activation of the downhole tool and then be effectively removed from the seat to allow further unimpeded operation of the downhole tool or a further change in the activation status of the downhole tool to be affected by a second activation device.

**[0024]** The method may therefore further comprise the steps of:

providing a second activation device adapted to pass through at least a part of the borehole and engage the seat, the second activation device comprising a core and an outer layer of material housing the core; transporting the second activation device in the flow of drilling fluid through the borehole to the seat of the downhole device, whereby the second activation device engages in the seat of the downhole tool; changing the state of activation of the downhole device when the second activation device engages with the seat, and eroding at least a portion of the second activation device with drilling fluid until the second activation device can pass through the seat.

**[0025]** The susceptibility to erosion of the second material of the core by the drilling fluid may be greater than that of the material of the outer layer. Erosion of the outer layer to expose the core may take more time than the subsequent erosion of the core. The susceptibility to erosion of the material of the core and material of the outer layer of the activation device by the drilling fluid may be adapted so that the activation device remains in substantially its original condition and having its original shape and/or size until after the activation device has contacted a downhole tool and the downhole tool has been activated, deactivated or reactivated.

**[0026]** The activation device may be sufficiently rigid and the outer layer or core have sufficient compressive strength to provide adequate resistance to drilling fluid pressure in the downhole well. The activation device is therefore able to facilitate operation of the downhole tool. When the outer layer is eroded to expose the chamber or core, the activation device may disintegrate and may pass through the seat and be washed away from the downhole tool by the drilling fluid in the downhole well. The activation device may be eroded after the step of changing the activation status of the downhole tool. The method of operating a downhole tool may therefore be particularly suited for repeat operation of a downhole tool.

**[0027]** The activation device may erode over a period of between 10 seconds and 20 minutes, optionally over a period of between 10 seconds and 15 minutes, normally over a period of between 10 seconds and 15 minutes and may be over a period of between 10 and 30 seconds when located in the seat member.

**[0028]** The method of operating a downhole tool may include activating the tool using a first activation device.

From this activated configuration the downhole tool may be deactivated using a second activation device that is substantially identical to the first activation device.

**[0029]** The method of operating the downhole tool may include the step of dropping the activation device into the borehole of the downhole well. This is typically the way of introducing an activation device into the borehole and has the advantage it does not require or rely on any additional equipment or tools for the deployment of the activation device. This reduces the dependence on specific tools and therefore the risk of downtime caused by tool failure.

**[0030]** The drilling fluid may be pumped through the borehole. The drilling fluid may be pumped down the borehole of the downhole well. Pumping is typically the method used to move the drilling fluid in the borehole and can be used to control the velocity and pressure of drilling fluid in the borehole. The drilling fluid may be drilling mud.

**[0031]** The velocity of the drilling fluid may be between 5 and 45 metres per second and normally slower than 20 metres per second. The velocity of the drilling mud is intended to be high enough to erode at least a portion of the activation device but not too high that the drilling fluid damages the and/or other downhole tools. If the velocity of the drilling fluid is not high enough, then at least a portion of the activation device will not be eroded or eroded sufficiently quickly for efficient operation of the downhole tool and further unimpeded operation of the downhole tool. At least a portion of the activation device may be eroded with drilling fluid and the activation device passes through the seat up to 5 minutes after the activation device has engaged in the seat.

**[0032]** Erosion of the outer layer of the activation device may be caused by friction. The erosion by friction may be abrasion, caused by particles of solids transported in the drilling fluid contacting the material of the outer layer and/or second material of the core of the activation device. The particles of solids may scratch, scrape and/or wear down the surface of the material of the outer layer and/or the second material of the core of the activation device. The particles of solid may be suspended in the drilling fluid. Erosion of the activation device by particles of solids transported in the drilling fluid does not require the use of further downhole tools or for example special chemicals to be added to drilling fluid. These solids are typically present in drilling fluid during normal use.

**[0033]** The activation device may be erodible such that it will collapse or implode. When the activation device is hollow, it does not need to be eroded completely but rather to an extent that the drilling fluid pressure is sufficient to crush the activation device.

**[0034]** An erodible activation device can be slowly eroded such that the activation device will not be substantially eroded on its way through the downhole well (borehole) or string even though it is in contact with the drilling fluid. Otherwise the activation device would be substantially eroded and therefore relatively useless by the time it reached the downhole tool, it not being able

to activate, deactivate or reactivate the downhole tool.

**[0035]** The second material of the core may be dissolvable. Dissolvable means the material can one or more of pass into solution in the drilling fluid; disperse; and disintegrate. The material of the outer layer and/or second material of the core may be corroded by the drilling fluid.

**[0036]** The preferred features of the first aspect of the invention can be incorporated into the second aspect of the invention and vice versa.

**[0037]** There is also herein described an activation device for use in a downhole well for activation of a downhole tool in the well, the downhole tool having a seat adapted to engage the activation device whereby engagement of the activation device in the seat changes the activation status of the downhole tool, the activation device being adapted for passage through the borehole of the well and being adapted to engage the seat of the downhole tool in the well to change the activation status of the downhole tool, the activation device comprising a body with at least one chamber at least partially housed within the body, and wherein the material of the body is adapted to resist erosion during passage of the activation device through the borehole of the well in normal operating conditions, and wherein the material of the body is adapted to be eroded by drilling fluid when the activation device is engaged in the seat in the downhole tool, whereby the drilling fluid erodes the seated activation device such that the activation device is able to pass through the seat.

**[0038]** The at least one chamber at least partially housed in the body may be in the centre of the activation device and may be a void, such that the activation device is hollow. The void may comprise a vacuum. If the at least one chamber is a void, then when the activation device is sufficiently eroded, it may collapse generating fragments of the activation device that are able to pass through the seat. The void means that only fragments of the body need to pass through the seat. The vacuum may make it more likely that the activation device collapses because there is a tendency for the activation device to implode.

**[0039]** The at least one chamber at least partially housed in the body may be at least one channel that extends from an outer surface towards the centre of the activation device. The at least one channel may extend across the activation device from one outer surface to another outer surface of the activation device. The at least one channel may provide fluid communication into or through the body of the activation device. The at least one channel may therefore provide a path for the flow of drilling fluid. The material of the body is adapted to be eroded by drilling fluid and so the at least one channel increases the surface area of the body that is susceptible to erosion and therefore may reduce the time taken for the activation device to be eroded and pass through the seat.

**[0040]** A portion of the body of the activation device

may be weighted to control the orientation of the activation device in the borehole and/or on the seat. This may help to control the flow of fluid through the at least one channel and so also erosion of the activation device.

5 **[0041]** The at least one chamber may alternatively contain a fluid. The fluid may be one or more of air; an inert gas; a liquid; oil; and water. The fluid may be at a pre-determined pressure or if the fluid is air it may be at atmospheric pressure. The fluid may affect the compressive strength of the body and/or activation device and this may be used to help promote or hinder fragmentation of the activation device after it has engaged the seat and the activation status of the downhole tool has been changed.

10 **[0042]** The at least one chamber may be sealed from the environment outside of the activation device and is optionally sealed by the outer layer. By sealing the at least one chamber, and if appropriate the fluid in the chamber from the environment outside of the activation device, the composition of the fluid or contents of the at least one chamber can be controlled and therefore also the compressive strength of the body and/or activation device can be controlled.

15 **[0043]** The body may have a compressive strength from 10 to 140MPa. Optionally the body has a compressive strength of between 60 and 100MPa. The body may have a compressive strength of between 70 and 90MPa. Normally the body has a compressive strength of 80MPa. The body may provide structural strength to the activation device. The body can provide the required structural strength if the compressive strength of the body is sufficient to withstand impact of the activation device against the sides of the borehole during passage of the activation device through the borehole of the well, the impact of the activation device on the seat and the force applied to the activation device through the drilling fluid to activate the downhole tool. The body may have a compressive strength such that the shape and size of the activation device remain substantially constant at least during passage of the activation device through the borehole of the well.

20 **[0044]** The material of the body may be one or more of cement; concrete; epoxy resin, ceramic, chipboard and medium-density fibreboard. The material of the body may be chosen to provide the activation device with the required structural strength. The material of the body may be impermeable to the drilling fluid and so will only be eroded by the drilling fluid. This may allow the user to control when the activation device is able to pass through the seat and/or disintegration of the activation device.

25 **[0045]** The compressive strength of the body typically depends on the material of the body. The compressive strength of a body comprising concrete may be between 80 and 100 MPa. The compressive strength of a body comprising epoxy resin may be between 80 and 120 MPa.

30 **[0046]** The activation device may comprise a substantially spherical ball or may be cylindrical in shape. The

seat of most downhole tools is adapted to receive a substantially spherical ball. This obviates the need to control the orientation of the activation device relative to the seat and/or tool and therefore optimises contact between the ball and the seat. The activation device may be a drop ball.

**[0047]** The activation device may have an external or outer diameter of between 10 and 100mm; optionally between 30 and 70mm; and normally 54mm. These external or outer diameters mean that the activation device is small enough to pass through the borehole of a downhole well and big enough to engage with a typical seat of a typical downhole tool to activate and/or deactivate the tool.

**[0048]** The at least one chamber may be in the centre of the activation and may have a diameter of between 2 and 80mm; normally between 6 and 49mm. These dimensions are sufficient to provide the activation device with a body of sufficient thickness to provide the resistance to erosion by the drilling fluid the activation device requires before and/or during passage of the activation device through the borehole of the well to the downhole tool.

**[0049]** The preferred features of the first and second aspects of the invention can be incorporated into the activation device described above and vice versa.

**[0050]** Embodiments of the present invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a cross-sectional perspective view of an activation device according to an embodiment of the present invention;

Figure 2 is a cross-sectional perspective view of an activation device according to an alternative embodiment of the present invention;

Figure 3 is a part cross-sectional perspective view of an activation device;

Figures 4 to 6 are cross-sectional perspective views of an activation device;

Figure 7 is a plan view of a mould for the core of an activation device;

Figure 8 is an exploded perspective view of a mould for an activation device;

Figure 9 is an exploded perspective view of an alternative mould for an activation device; and

Figure 10 is a cross-sectional view of part of a downhole tool with a seat; an activation device according to an embodiment of the present invention is engaged in the seat.

**[0051]** Figure 1 shows an activation device in the form of a ball 10 with an outer layer 12 made of concrete and a core 14 made of wax. The outer layer 12 of the ball 10 is erodible by, but impermeable to, drilling mud. The ball 10 is generally spherical.

**[0052]** In use the impermeable outer layer 12 prevents the drilling mud from coming into contact with the core

14 of wax when the ball 10 is being transported by the drilling mud from the surface to the downhole tool (not shown). As the temperature of the drilling mud increases the wax is heated and melts. The outer layer 12 contains the core 14 of melted wax as the ball 10 is transported from the surface to the downhole tool (not shown). The outer layer 12 may insulate the core 14 of wax from the heat of the drilling mud thereby delaying the melting of the core 14 of wax.

**[0053]** The compressive strength of the ball 10 is reduced or weakened when the wax of core 14 has melted and is in liquid form.

**[0054]** When the ball 10 is seated on the downhole tool the pressure of drilling mud acting on the ball 10 activates the downhole tool. With the ball 10 now stationary, the drilling mud erodes the outer layer 12 of the ball 10, exposing the core 14 of wax. When the thickness of the ball 10 is reduced sufficiently, the ball 10 typically disintegrates and the fragments of the outer layer 12 and core 14 of wax are flushed into the drilling mud.

**[0055]** The wax (of core 14) is typically a hydrocarbon wax, and usually a paraffin wax of a mixture of alkanes having the general chemical formula of  $C_nH_{2n+2}$  with a value of n between 20 and 40.

**[0056]** The ball 10 in this example has an external diameter of 54mm; the core 14 has a diameter of 40mm. The core 14 may have a diameter of between 25 and 48mm.

**[0057]** The outer layer 12 may be made only of cement. The concrete described above typically contains cement, sand and/or gravel. The cement binds the sand and/or gravel together to form concrete. The cement may include one or more of the chemical elements aluminium; calcium; iron; and silicon. The cement may incorporate limestone.

**[0058]** The outer layer 12 of the ball 10 is made from a material that can be eroded by drilling mud and is alternatively made of one or more of epoxy resin; ceramic; and MOLYKOTE (RTM) as supplied by Dow Corning Corporation.

**[0059]** The core 14 of the ball 10 may alternatively be made of sand; the sand may be compacted. In use, the external outer layer 12 of the ball 10 provides the ball with a defined structure whilst the ball is transported downhole and seated on the downhole tool. As soon as the outer layer 12 of cement has been eroded enough to expose the sand of the core 14 to the drilling mud, the sand is then flushed into the mud system including the drilling mud. The remaining outer layer 12 is then an empty shell that easily fragments under the force applied by the drilling fluid flowing past the seat and is also flushed into the mud system.

**[0060]** Alternatively, the core 14 of ball 10 is hollow.

**[0061]** Examples of a downhole tool that could be operated using an activation ball according to an aspect of the present invention include hole-enlargers; activation devices in a core barrel assembly; inflatable packers; circulating subs and multi-activation subs.

**[0062]** Figure 2 shows a ball 20 with an outer layer 22 made of concrete and a core 24 made of salt. The salt is typically sodium chloride (NaCl). During manufacture, the core 24 is typically covered in a layer 26 of wax to protect the concrete from the salt. The wax is typically a hydrocarbon wax but may be any coating that provides the necessary protection to the outer layer from the core and does not affect the compressive strength of the ball or erodibility of the core. In an alternative embodiment the outer layer 22 of concrete contacts the salt core 24 and there is no layer 26 of wax.

**[0063]** The ball 20 having a core 24 of salt typically has an impermeable outer layer 22 or coating made of concrete. In use, the outer layer 22 prevents the core 24 from being eroded or dissolved when the ball 20 is submerged in the drilling mud. When the outer layer 22 of concrete has been eroded enough to expose the salt of the core 24 to the drilling mud, the salt is easily dissolved and/or eroded by the drilling mud and fragments of the salt core 24 pass into the mud system. Any remaining fragments of the outer layer 22 are also flushed through the downhole tool and into the mud system.

**[0064]** The ball 20 has an external diameter of 54mm; the core 24 has a diameter of 52mm.

**[0065]** Alternatively, the outer layer 22 of the ball 20 is made from epoxy resin, or ceramic. Alternatively, the outer layer 22 of the ball 20 is made from one or more of an ester; fluorinated; fluorosilicone; mineral oil; polyalkyleneglycol; polyalphaolephin; perfluoropolyether; silicone; synthetic blend; and siloxane grease. The outer layer may be MOLYKOTE (RTM) as supplied by Dow Corning Corporation.

**[0066]** The epoxy resin outer layer 22 is typically resistant to attack by chemicals and/or heat. The epoxy resin outer layer 22 provides the salt core 24 with good mechanical protection.

**[0067]** The concrete described above contains cement, sand and/or gravel. The cement binds the sand and/or gravel together to form concrete. The cement may include one or more of the chemical elements aluminium; calcium; iron; and silicon. The cement may incorporate limestone. The outer layer 22 provides the ball 20 with a defined shape and size whilst the ball is transported downhole.

**[0068]** Alternatively the core 24 is made of sand; the sand may be compacted.

**[0069]** In use the impermeable outer layer 22 prevents the drilling mud from coming into contact with the core 24 of salt when the ball 20 is being transported by the drilling mud from the surface to the downhole tool (not shown). The outer layer 22 makes the ball 20 resistant to erosion by the drilling mud when it is travelling downhole towards the tool (not shown). The outer layer 22 may also protect the ball 20 from damage caused by the ball contacting the sides of the borehole and/or other obstacles in the flow path of the drilling mud between the surface and the downhole tool.

**[0070]** When the ball 20 is seated in the downhole tool

the pressure of drilling mud acting on the ball 20 is used to activate the downhole tool. With the ball 20 now stationary, the ball 20 is susceptible to erosion and the drilling mud erodes the outer layer 22 of the ball 20, exposing the core 24 of salt.

**[0071]** Erosion of the outer layer 22 and core 24 of the ball 20 by the drilling fluid when it is seated in the downhole tool reduces the diameter of the ball 20. When the diameter of the ball 20 has been sufficiently reduced, the ball 20 is able to pass through the seat of the downhole tool. The ball 20 now only comprises the salt core 24 because the outer layer 22 has already been eroded away by the drilling fluid. Further erosion of the salt core 24 by the drilling mud is now possible as what remains of the salt core 24 passes through the seat and into the borehole below the tool. At this stage the core 24 of the ball 20 is not protected by the outer layer 22 and is susceptible to erosion by the drilling mud.

**[0072]** Usually up to 5 minutes after the ball 20 has first contacted the downhole tool, the outer layer 22 and core 24 of the ball 20 have been eroded and fragments of the ball 20 washed into the drilling mud. These fragments are small enough so that they do not interfere with the operation of other downhole tools and can be carried or suspended in the drilling mud and therefore washed out of the borehole by the drilling mud.

**[0073]** The velocity of the drilling mud moving past the ball 20 on the seat of the downhole tool (not shown) is normally between 5 and 45 metres per second, optionally less than 20 metres per second.

**[0074]** Figure 10 shows a ball 100 in a downhole tool 101. The ball 100 has passed through a central bore 102 of the downhole tool 101 and is engaged in the seat 103. The seat 103 has slots 104 that allow fluid to flow past the ball 100 in the direction of the arrows 105a and 105b.

**[0075]** The outer layer of the activation ball 20 comprises a material that remains substantially intact when travelling down the borehole to the downhole tool. The outer layer of concrete, epoxy resin or ceramic is therefore not eroded, such that the salt core is not exposed, until the ball is on the seat.

**[0076]** Examples of a downhole tool that could be operated using the activation ball 20 include hole-enlargers; activation devices in a core barrel assembly; inflatable packers; circulating subs and multi-activation subs.

**[0077]** In use, the ball 20 travels through the borehole until it reaches the seat of the downhole tool. The seat catches the ball 20, the ball 20 substantially blocking the throughbore of the downhole tool. The seat normally has slots, apertures or other suitable forms of bypass channels that remain open to allow drilling fluid to continue to flow past the ball 20 when it is in the seat. The flow of drilling fluid past the ball on the seat is typically reduced compared to the flow of drilling fluid through a central channel of the downhole tool that is possible when the seat is empty.

**[0078]** When the activation ball 20 is in the seat, the pressure of the drilling fluid in the borehole increases.

The increased force acting on the ball 20 is used to operate the downhole tool, pushing at least part of the downhole tool downwards in a downstream direction.

**[0079]** The ball is eroded by the action of the drilling mud and/or components of the drilling mud that pass the ball when it is in the seat and the drilling mud is flowing through the slots in the seat.

**[0080]** Figure 3 shows a ball 30 made of concrete 32. The ball 30 has three hollow channels 37a, 37b and 37c that extend from the outer surface 35 of the ball 30 to the centre 38. The hollow channels 37a, 37b and 37c have an opening 33 on the outer surface of the ball 30 and converge at the centre 38 of the ball 30 to produce a chamber 39. The hollow channels 37a, 37b and 37c provide a flow path for drilling mud and therefore promote erosion of the ball 30. On break up of the ball 30 the pieces of cement 32 are relatively small and easily pass through the downhole tool (not shown) carried by the drilling mud.

**[0081]** The ball 30 has an external diameter of 54mm; the hollow channels 37a, 37b and 37c have an internal diameter of 8mm. The hollow channels 37a, 37b and 37c may have an internal diameter of between 8 and 10mm.

**[0082]** Alternatively, the concrete 32 of the ball 30 is a mixture of cement and pebbles. The pebbles range in size from 1 to 2mm in diameter. The material of the ball is a conglomerate. Hollow channels 37a, 37b and 37c are drilled in the concrete and pebble mixture as described above.

**[0083]** Again alternatively, the concrete 32 of the ball 30 is a mixture of cement and particles of lead. The particles of lead range in size from 2 to 3mm in diameter. The particles of lead add to the mass of the ball 30 and thereby can help promote delivery of the ball. Hollow channels 37a, 37b and 37c are drilled in the concrete as described above.

**[0084]** In an alternative embodiment there may be more than three hollow channels 37a, 37b and 37c.

**[0085]** Figures 4, 5 and 6 show a ball 40 referred to as a "dart ball". The ball 40 is made of concrete 42. The ball 40 has radial hollow channels 41 a and 41 b that extend from the outer surface 45 of the ball 40 to a central hollow channel 49. The hollow channels 41 a and 41 b have an opening 43 on the outer surface of the ball 40 and converge in, and are in fluid communication with, the central hollow channel 49. The hollow channel 49 passes through the ball 40, as shown in Figure 5. The ball 40 also has hollow conduits 50a-f that extend from the outer surface 45 of the ball 40 towards, but are not in fluid communication with, the central hollow channel 49. The hollow channels 41 a and 41 b have an opening 43 on the outer surface of the ball 40 and converge in, and are in fluid communication with, the central hollow channel 49. There are other radial hollow channels and hollow conduits in the ball 40; these are shown in Figures 5 and 6. In use, the hollow channels 41 a and 41 b act like the fins and help the ball 40 to "fly" through the drilling mud or water column as appropriate. In use, the hollow con-

duits 50a-f have a dead-end as described above and act as "worm holes", increasing the surface area of the ball at which erosion can occur. As erosion of the ball continues, the hollow conduits 50a-f will increase in length and penetrate the central hollow channel 49, further helping the erosion process and subsequent breakup of the ball.

**[0086]** The ball 40 is flattened at the ends of the central hollow channel 49. The concrete 42 of the lower third (1/3) of the ball 40, indicated by the hatching 51, includes lead shot (not shown). The lead shot has a diameter in the range of 2 to 3mm and in use, helps to weight and orientate the ball 40 in the downhole well (not shown). In use, the drilling mud passes through the central hollow channel 49 also helping to orientate the ball 40.

**[0087]** The ball 40 has an external diameter of 54mm; the central hollow channel 49 has an internal diameter of 12mm; the angled radial hollow channels 41 a and 41 b have an internal diameter of 5mm; the hollow conduits 50a-f have an internal diameter of 8mm.

**[0088]** The ball 40 shown in Figure 6 further includes further hollow conduits 60a-f that extend at right angles to the hollow conduits 50a-f shown in Figures 4 and 5. Like the hollow conduits 50a-f, the hollow conduits 60a-f extend from the outer surface 45 towards the centre of the ball 40.

**[0089]** Figure 7 shows a mould for the manufacture of the core 14 of the ball 10 shown in Figure 1. The mould 70 is made of silicone and has hemispherical depressions 71 spaced across a panel 72. In use, sand (not shown) is poured into the mould 70 and a glue (not shown) is added to fill the pores in the sand. Excess sand is removed to produce a half ball or hemisphere. Once the glue has dried, the half balls are taken out of the mould 70 and the two half balls glued together to make a ball or sphere. The hemispheres have a diameter of 25mm. In an alternative embodiment the hemispheres have a diameter of between 40 and 45mm.

**[0090]** Figures 8 and 9 show two types of mould for the manufacture of the balls 10, 20, 30 and 40 shown in Figures 1, 2, 3 and 4-6 respectively. The moulds 80 and 90 are made of steel. Using the mould shown in Figure 8, it can sometimes be difficult to remove the ball from the mould without damaging the ball. The mould shown in Figure 9 is easier to separate and remove the ball from and therefore it is less likely that the ball is damaged when being removed from the mould 90.

**[0091]** The following materials are used: sand; high resistance cement (80MPa); salt; glue (light glue); epoxy laminating resin; wax; and petroleum jelly.

**[0092]** The following equipment is used: silicon mould (diameter of hollows 25 & 40mm); water drilling machine; concrete drill (8 & 10mm drill bit); hammer; wrench; and glass ball.

**[0093]** There is herein described a method of manufacturing the ball 10 shown in Figure 1, the ball having a hollow core 14. It is difficult to manufacture the ball shown in Figure 1 because the ball must have a hollow centre

that is concentric with the external surface of the concrete ball. To produce a hollow centre to the concrete ball, typically a glass ball is used as an object about which the concrete is poured. Using the mould 80 shown in Figure 8, the screws 81 and pins 82 are inserted into the mould 80 and the glass ball is laid on top of the pins 82 and screws 81. It is important that the pins 82 and screws 81 are inserted into the mould at the correct length to obtain the required concentricity. The internal faces of the mould are lubricated with petroleum jelly. Other suitable lubricants including molybdenum-based lubricants and silicone-based lubricants could be used.

**[0094]** One mould half 85 of the mould 80 can be pre-filled with concrete before inserting the glass ball (not shown). This makes it easier to ensure that concrete fully surrounds the glass ball. The other mould half 86 is then offered up to the mould half 85 and the two mould halves 85 and 86 are connected together using the screws 87. Concrete can then be poured into the mould through the filling hole 88 located in the mould half 85. Care is taken not to crush the glass ball when filling the mould 80 with concrete.

**[0095]** It is important to minimise as much as possible air pockets trapped inside the cement. A rubber hammer is used to gently tap the mould so that air is driven from the cement and escapes the mould. A vibrating plate could be used instead.

**[0096]** With the mould 80 filled with concrete, the concrete is allowed to dry and after 20 minutes the two halves of the mould are carefully separated. At this stage the concrete is not completely dry but the ball (not shown in Figure 8) is strong enough to be manipulated. The concrete can be allowed to dry for between 30 and 40 minutes. It is important however that the concrete is removed from the mould before the concrete sticks to the face of the mould making the removal of the ball difficult without breaking the ball.

**[0097]** When the ball is removed from the mould 80 there are holes in the outer wall of the ball caused by the screws 81 and pins 82 that penetrate the inside of the mould. These holes are now filled with fresh concrete and the ball is left to dry for 21 days to ensure the concrete obtains its best resistance.

**[0098]** The mould 90 shown in Figure 9 is used in the same way as the mould 80 shown in Figure 8. The difference between the moulds is that the two mould halves 85 and 86 of mould 80 have been further split into quarters 95a, 95b and 96a, 96b. Screws 99 are used to hold together quarters 95a and 95b and screws 100 are used to hold together quarters 96a and 96b.

**[0099]** The method of manufacturing the other balls 10, 20, 30 and 40 shown in Figures 1 to 6 is similar to that described above. The differences are outlined below.

**[0100]** There is herein described a method of manufacturing the ball 10 shown in Figure 1, the ball having a core 24 of wax. The first step is to manufacture a wax ball (not shown). A glass ball is used; the glass ball is filled with wax. The glass ball is pre-heated to avoid ther-

mic shock and also to make sure the wax remains in a liquid state during the filling. This minimises the chance of air pockets forming in the wax as it solidifies. A venting hole is provided in the glass ball so that air can escape during filling. The wax ball is then allowed to cool and harden and then placed in the mould 80 and concrete added to the mould as described above; the wax ball replaces the glass ball described above with reference to the ball 10 of Figure 1 with a hollow core 24.

**[0101]** There is herein described a method of manufacturing the ball 10 shown in Figure 1, the ball having a core 24 of sand. The first step is to manufacture the sand ball (not shown). The sand ball is sufficiently consolidated to withstand the manufacturing process but also soft enough to be washed away by drilling mud when the concrete shell has been eroded and abraded to reveal the core 24 of sand. Glue is used as a binding agent to bind or bond together the grains of sand. The glue can be starch; methylcellulose; clay and/or dextrin based. The glue must have a low viscosity and relatively low adhesive strength.

**[0102]** There is herein described a method of manufacturing the ball 20 shown in Figure 2, the ball having a core 24 of salt. The first step is to manufacture a salt ball (not shown) having an external diameter of 45mm. The salt ball is milled using a computer numerical control (CNC) milling machine. Salt is corrosive and therefore to avoid problems caused by small particles of salt produced by the CNC machine coming into contact with surrounding equipment, the salt ball is dipped in oil before the ball is milled.

**[0103]** After milling an impermeable protective layer or coating 26 of wax is applied to the salt ball to protect the salt from environmental conditions and the surrounding environment from the salt. The protective layer also reduces the chance of the salt contaminating the concrete. Such contamination would prevent the cement from drying.

**[0104]** The ball 20 shown in Figure 2 also has an outer layer 22 made of concrete. The outer layer 22 prevents water and other liquids in the drilling mud reacting with and/or eroding the core 24 of the salt when the ball 20 is added to the drilling mud or other fluid in a borehole of a downhole well.

**[0105]** In an alternative embodiment, the core 24 of salt has an outer layer of epoxy resin; or ceramic instead of concrete as described above.

**[0106]** The epoxy resin is a two-part epoxy laminating resin. The first component is the resin and the second component is a hardener. The resin comprises epichlorohydrin and bisphenol-A. The hardener comprises triethylenetetramine (TETA).

**[0107]** The proportions used are two doses resin and one dose hardener. It is important to mix the resin and hardener slowly to avoid the formation of air bubbles. When the components have been mixed the mixture must be used within 50 minutes.

**[0108]** The resin is poured onto the ball until the ball is

fully covered with a uniform layer of resin. It is important to minimise the contact points on which the ball rests and/or sits. The resin is then dried at a temperature of 25°C for between 8 and 14 hours.

[0109] Alternatively the core 24 of the ball 20 has an outer layer of ceramic. The core 24 of salt is covered with a ceramic powder and then placed in an oven. The temperature is raised until the powder melts. When cooling, the powder solidifies providing the protective outer layer.

[0110] Alternatively the core 24 of the ball 20 has an outer layer of grease and/or oil. The outer layer is allowed to dry before the activation ball is used or brought into contact with the drilling fluid.

[0111] There is herein described a method of manufacturing the ball 30 shown in Figure 3, the ball 30 being made of concrete 32 and having three hollow channels 37a, 37b and 37c. Either of the moulds shown in Figures 8 or 9 can be used to make this ball but using the mould shown in Figure 8 makes it easier to subsequently drill holes in the ball. This is because the screws 81 and pins 82 generate holes in the ball that can be used as pilot holes when subsequently drilling the channels 37a, 37b and 37c in the ball.

[0112] The channels 37a, 37b and 37c are drilled when the concrete has been dried for at least one week. A small hole with a diameter of 4mm (+/-1 mm) is drilled first and then the channels 37a, 37b and 37c are drilled at a diameter of 8mm. It is important to stop drilling in the middle of the ball, otherwise there is a risk of damaging the ball when the drill exits the other side of the ball.

[0113] Modifications and improvements can be incorporated without departing from the scope of the invention. Certain embodiments of the invention avoid the need for ball catcher devices to catch the activation device when it passes through the downhole tool, freeing the tool from design constraints related to the limited capacity of the catcher device for activation balls.

[0114] Certain embodiments of the invention allow an activation ball to be eroded and then move thorough a seat of a first tool, and onto the seat of a second tool further down the borehole to activate the second tool.

[0115] Certain embodiments of the invention allow relaxation of manufacturing tolerances for the ball which merely needs to occlude the seat and then be eroded. Also, activation devices according to the invention do not require the same precise pressure increase in the activation regime as is the case with deformable balls, so permit easier and more accurate activation and de-activation with lower specifications of equipment and training.

## Claims

1. An activation device (10,20,30,40) for use in a downhole well for activation of a downhole tool (101) in the well, the downhole tool (101) having a seat (103) adapted to engage the activation device

(10,20,30,40) whereby engagement of the activation device (10,20,30,40) in the seat (103) changes the activation status of the downhole tool (101), the activation device being adapted for passage through the borehole of the well and being adapted to engage the seat (103) of the downhole tool (101) in the well to change the activation status of the downhole tool (101), **characterised in that:**

the activation device (10,20,30,40) comprises an outer layer (12,22) and a core (14,24) housed within the outer layer (12,22), wherein the core (14,24) comprises a material that is more susceptible to erosion than the material of the outer layer (12,22); and wherein the material of the outer layer (12,22) is adapted to resist erosion during passage of the activation device (10,20,30,40) through the borehole of the well in normal operating conditions, and wherein the material of the outer layer (12,22) and the core (14,24) are adapted to be eroded by drilling fluid when the activation device (10,20,30,40) is engaged in the seat (103) in the downhole tool (101), whereby the drilling fluid erodes the seated activation device (100) such that the activation device (10,20,30,40) is able to pass through the seat (103).

2. An activation device (10,20,30,40) according to claim 1 wherein the core (14,24) has a compressive strength from 10 to 140MPa.

3. An activation device (10,20,30,40) according to claim 1 and claim 2 wherein the material of the outer layer (12,22) is one or more of cement, concrete, epoxy resin, ceramic, MOLYKOTE (RTM), ester, flourosilicone, mineral oil, polyalkyleneglycol; poly-alphaolephin, perfluoropolyether, silicone, and siloxane grease.

4. An activation device (10,20,30,40) according to any preceding claim wherein the material of the core (14,24) is one or more of wax, salt, and sand.

5. An activation device (10,20,30,40) according to any preceding claim wherein the activation device (10,20,30,40) is adapted to be eroded by the flow of drilling fluid past the seated activation device (100).

6. An activation device (10,20,30,40) according to any preceding claim wherein the core (14,24) comprises a material adapted to change state from solid to liquid when exposed to normal temperatures in the environment of the seat (103).

7. A method of operating a downhole tool (101) in a borehole of an oil or gas well, the downhole tool (101)

having a seat (103) for engaging an activation device (10,20,30,40), the method comprises the steps of:

providing an activation device (10,20,30,40) adapted to pass through at least a part of the borehole and engage the seat (103), the activation device (10,20,30,40) comprising a core (14,24) and an outer layer (12,22) of material housing the core (14,24); wherein the core (14,24) comprises a material that is more susceptible to erosion than the material of the outer layer (12,22), whereby erosion of the outer layer (12,22) to expose the core (14,24) takes more time than the subsequent erosion of the core (14,24);  
 transporting the activation device (10,20,30,40) in a flow of drilling fluid through the borehole from an insertion point in the borehole to the seat (103) of the downhole tool (101), whereby the activation device (10,20,30,40) engages in the seat (103) of the downhole tool (101);  
 changing the state of activation of the downhole tool (101) when the activation device (10,20,30,40) engages with the seat (103), and eroding at least a portion of the activation device (10,20,30,40) with drilling fluid until the activation device (10,20,30,40) can pass through the seat (103).

8. A method according to claim 7 wherein the activation device (10,20,30,40) is eroded by flowing the drilling fluid past the activation device (10,20,30,40) when the activation device (10,20,30,40) is in the seat (103) of the downhole tool (101).
9. A method according to claim 7 or claim 8 wherein the activation device (10,20,30,40) is eroded after the step of changing the activation status of the downhole tool (101).
10. A method according to any of claims 7 to 9 wherein the eroded activation device passes through the seat (103) and is washed away from the downhole tool (101) by the drilling fluid.
11. A method according to any of claims 7 to 10 wherein the activation device (10,20,30,40) erodes over a period of between 10 seconds and 20 minutes when located on the seat member (103).
12. A method according to any of claims 7 to 11 wherein the velocity of the drilling fluid is between 5 and 45 metres per second.
13. A method according to any of claims 7 to 12 wherein the activation status of the downhole tool (101) is changed a second time by a second activation device (10,20,30,40), the method comprising the fur-

ther steps of:

providing a second activation device (10,20,30,40) adapted to pass through at least a part of the borehole and engage the seat (103), the second activation device (10,20,30,40) comprising a core (14,24) and an outer layer (12,22) of material housing the core (14,24); wherein the core (14,24) comprises a material that is more susceptible to erosion than the material of the outer layer (12,22), whereby erosion of the outer layer (12,22) to expose the core (14,24) takes more time than the subsequent erosion of the core (14,24);  
 transporting the second activation device (10,20,30,40) in the flow of drilling fluid through the borehole to the seat (103) of the downhole tool (101), whereby the second activation device (10,20,30,40) engages in the seat (103) of the downhole tool (101);  
 changing the state of activation of the downhole tool (101) when the second activation device (10,20,30,40) engages with the seat (103), and eroding at least a portion of the second activation device (10,20,30,40) with drilling fluid until the second activation device (10,20,30,40) can pass through the seat (103).

## 30 Patentansprüche

1. Aktivierungsgerät (10, 20, 30, 40) zur Verwendung in einer Untertagequelle zum Aktivieren eines Untertagewerkzeugs (101) in der Quelle, wobei das Untertagewerkzeug (101) einen Sitz (103) aufweist, der angepasst ist, um das Aktivierungsgerät (10, 20, 30, 40) in Eingriff zu nehmen, wobei der Eingriff des Aktivierungsgeräts (10, 20, 30, 40) in den Sitz (103) den Aktivierungsstatus des Untertagewerkzeugs (101) ändert, wobei das Aktivierungsgerät zum Durchlaufen des Bohrlochs der Quelle angepasst ist und angepasst ist, um den Sitz (103) des Untertagewerkzeugs (101) in der Quelle in Eingriff zu nehmen, um den Aktivierungsstatus des Untertagewerkzeugs (101) zu ändern, **dadurch gekennzeichnet, dass:**

das Aktivierungsgerät (10, 20, 30, 40) eine äußere Schicht (12, 22) und einen Kern (14, 24), der innerhalb der äußeren Schicht (12, 22) untergebracht ist, umfasst,  
 wobei der Kern (14, 24) ein Material umfasst, das anfälliger für Erosion als das Material der äußeren Schicht (12, 22) ist;  
 und wobei das Material der äußeren Schicht (12, 22) so angepasst ist, dass es, während das Aktivierungsgerät (10, 20, 30, 40) das Bohrloch der Quelle durchläuft, unter normalen Betriebsbe-

- dingungen Erosion widersteht,  
und wobei das Material der äußeren Schicht (12, 22) und des Kerns (14, 24) so angepasst ist, dass es durch Bohrspülung erodiert, wenn das Aktivierungsgerät (10, 20, 30, 40) im Sitz (103) im Untertagewerkzeug (101) in Eingriff genommen ist, wobei die Bohrspülung das sitzende Aktivierungsgerät (100) erodiert, sodass das Aktivierungsgerät (10, 20, 30, 40) dazu in der Lage ist, den Sitz (103) zu durchlaufen.
2. Aktivierungsgerät (10, 20, 30, 40) nach Anspruch 1, wobei der Kern (14, 24) eine Druckfestigkeit von 10 bis 140 MPa aufweist.
  3. Aktivierungsgerät (10, 20, 30, 40) nach Anspruch 1 und 2, wobei das Material der äußeren Schicht (12, 22) eines oder mehrere von Zement, Beton, Epoxidharz, Keramik, MOLYKOTE<sup>®</sup>, Ester, Fluorsilikon, Mineralöl, Polyalkylenglycol; Polyalphaolefin, Perfluoropolyether, Silikon und Siloxanfett ist.
  4. Aktivierungsgerät (10, 20, 30, 40) nach einem vorhergehenden Anspruch, wobei das Material des Kerns (14, 24) eines oder mehrere von Wachs, Salz und Sand ist.
  5. Aktivierungsgerät (10, 20, 30, 40) nach einem vorhergehenden Anspruch, wobei das Aktivierungsgerät (10, 20, 30, 40) so angepasst ist, dass es durch den Bohrspülungsfluss am sitzenden Aktivierungsgerät (100) vorbei erodiert.
  6. Aktivierungsgerät (10, 20, 30, 40) nach einem vorhergehenden Anspruch, wobei der Kern (14, 24) ein Material umfasst, das so angepasst ist, dass es seinen Status von fest zu flüssig ändert, wenn es normalen Temperaturen in der Umgebung des Sitzes (103) ausgesetzt ist.
  7. Verfahren zur Betätigung eines Untertagewerkzeugs (101) in einem Bohrloch einer Öl- oder Gasquelle, wobei das Untertagewerkzeug (101) einen Sitz (103) aufweist, um ein Aktivierungsgerät (10, 20, 30, 40) in Eingriff zu nehmen, wobei das Verfahren die folgenden Schritte umfasst:
 

Bereitstellen eines Aktivierungsgeräts (10, 20, 30, 40), das so angepasst ist, dass es zumindest einen Teil des Bohrlochs durchläuft und den Sitz (103) in Eingriff nimmt, wobei das Aktivierungsgerät (10, 20, 30, 40) einen Kern (14, 24) und eine äußere Schicht (12, 22) an Material, das den Kern (14, 24) beherbergt, umfasst; wobei der Kern (14, 24) ein Material umfasst, das anfälliger für Erosion als das Material der äußeren Schicht (12, 22) ist, wobei die Erosion der äußeren Schicht (12, 22) zum Freilegen des Kerns
- (14, 24) mehr Zeit in Anspruch nimmt als die nachfolgende Erosion des Kerns (14, 24);  
Transportieren des Aktivierungsgeräts (10, 20, 30, 40) in einem Bohrspülungsfluss durch das Bohrloch von einer Eintrittsstelle im Bohrloch zum Sitz (103) des Untertagewerkzeugs (101), wobei das Aktivierungsgerät (10, 20, 30, 40) den Sitz (103) des Untertagewerkzeugs (101) in Eingriff nimmt;  
Ändern des Aktivierungsstatus des Untertagewerkzeugs (101), wenn das Aktivierungsgerät (10, 20, 30, 40) den Sitz (103) in Eingriff nimmt, und  
Erodieren von zumindest einem Teil des Aktivierungsgeräts (10, 20, 30, 40) mit der Bohrspülung, bis das Aktivierungsgerät (10, 20, 30, 40) den Sitz (103) durchlaufen kann.
8. Verfahren nach Anspruch 7, wobei das Aktivierungsgerät (10, 20, 30, 40) erodiert wird, indem die Bohrspülung am Aktivierungsgerät (10, 20, 30, 40) vorbei fließt, wenn sich das Aktivierungsgerät (10, 20, 30, 40) im Sitz (103) des Untertagewerkzeugs (101) befindet.
  9. Verfahren nach Anspruch 7 oder Anspruch 8, wobei das Aktivierungsgerät (10, 20, 30, 40) nach dem Schritt des Änderns des Aktivierungsstatus des Untertagewerkzeugs (101) erodiert wird.
  10. Verfahren nach einem der Ansprüche 7 bis 9, wobei das erodierte Aktivierungsgerät den Sitz (103) durchläuft und von der Bohrspülung vom Untertagewerkzeug (101) weggespült wird.
  11. Verfahren nach einem der Ansprüche 7 bis 10, wobei das Aktivierungsgerät (10, 20, 30, 40) über einen Zeitraum zwischen 10 Sekunden und 20 Minuten erodiert, wenn es sich auf dem Sitzelement (103) befindet.
  12. Verfahren nach einem der Ansprüche 7 bis 11, wobei die Geschwindigkeit der Bohrspülung zwischen 5 und 45 Metern pro Sekunde beträgt.
  13. Verfahren nach einem der Ansprüche 7 bis 12, wobei der Aktivierungsstatus des Untertagewerkzeugs (101) ein zweites Mal durch ein zweites Aktivierungsgerät (10, 20, 30, 40) geändert wird, wobei das Verfahren die folgenden weiteren Schritte umfasst:
 

Bereitstellen eines zweiten Aktivierungsgeräts (10, 20, 30, 40), das so angepasst ist, dass es zumindest einen Teil des Bohrlochs durchläuft und den Sitz (103) in Eingriff nimmt, wobei das zweite Aktivierungsgerät (10, 20, 30, 40) einen Kern (14, 24) und eine äußere Schicht (12, 22) an Material, das den Kern (14, 24) beherbergt,

umfasst; wobei der Kern (14, 24) ein Material umfasst, das anfälliger für Erosion als das Material der äußeren Schicht (12, 22) ist, wobei die Erosion der äußeren Schicht (12, 22) zum Freilegen des Kerns (14, 24) mehr Zeit in Anspruch nimmt als die nachfolgende Erosion des Kerns (14, 24);

Transportieren des zweiten Aktivierungsgeräts (10, 20, 30, 40) im Bohrspülungsfluss durch das Bohrloch zum Sitz (103) des Untertagewerkzeugs (101), wobei das zweite Aktivierungsgerät (10, 20, 30, 40) den Sitz (103) des Untertagewerkzeugs (101) in Eingriff nimmt;

Ändern des Aktivierungsstatus des Untertagewerkzeugs (101), wenn das zweite Aktivierungsgerät (10, 20, 30, 40) den Sitz (103) in Eingriff nimmt, und

Erodieren von zumindest einem Teil des zweiten Aktivierungsgeräts (10, 20, 30, 40) mit einer Bohrspülung, bis das zweite Aktivierungsgerät (10, 20, 30, 40) den Sitz (103) durchlaufen kann.

## Revendications

1. Un dispositif d'activation (10,20,30,40) utilisé dans un puits de forage pour l'activation d'un outil de fond (101) dans le puits, l'outil de fond (101) possédant un siège (103) adapté pour engager le dispositif d'activation (10,20,30,40), l'engagement du dispositif d'activation (10,20,30,40) dans le siège (103) modifiant l'état d'activation de l'outil de fond (101), le dispositif d'activation étant adapté pour le passage dans le trou de sondage du puits, et étant adapté pour engager le siège (103) de l'outil de fond (101) dans le puits de façon à modifier l'état d'activation de l'outil de fond (101),

**caractérisé en ce que :**

le dispositif d'activation (10,20,30,40) comprend une couche extérieure (12,22) et une âme (14,24) contenue au sein de la couche extérieure (12,22),

l'âme (14,24) étant composée d'un matériau plus sensible à l'érosion que le matériau de la couche extérieure (12,22) ;

et le matériau de la couche extérieure (12,22) étant adapté pour résister à l'érosion au cours du passage du dispositif d'activation (10,20,30,40) à travers le trou de sondage du puits lors de l'utilisation normale,

et tant le matériau de la couche extérieure (12,22) que l'âme (14,24) étant adaptés pour être érodés par du fluide de forage lorsque le dispositif d'activation (10,20,30,40) s'engage dans le siège (103) de l'outil de fond (101), le dispositif d'activation à siège (100) subissant une érosion par le fluide de forage de sorte que

le dispositif d'activation (10,20,30,40) soit en mesure de passer à travers le siège (103).

2. Un dispositif d'activation (10,20,30,40) selon la revendication 1, dans lequel l'âme (14,24) présente une force de compression comprise entre 10 et 140MPa.
3. Un dispositif d'activation (10,20,30,40) selon la revendication 1 et la revendication 2, le matériau de la couche extérieure (12,22) étant un ou plusieurs des suivants : ciment, béton, résine époxy, céramique, MOLYKOTE<sup>(RTM)</sup>, ester, fluorosilicone, huile minérale, polyalkylène glycol, polyalphaoléfine, perfluoropolyéther, silicone, graisse au siloxane.
4. Un dispositif d'activation (10,20,30,40) selon une quelconque des revendications précédentes, le matériau de l'âme (14,24) étant un ou plusieurs des suivants : cire, sel, sable.
5. Un dispositif d'activation (10,20,30,40) selon une quelconque des revendications précédentes, le dispositif d'activation (10,20,30,40) étant adapté pour subir une érosion par l'écoulement de fluide de forage par le dispositif d'activation calé (100).
6. Un dispositif d'activation (10,20,30,40) selon une quelconque des revendications précédentes, l'âme (14,24) étant composée d'un matériau adapté pour modifier l'état de solide à liquide lors de l'exposition à des températures normales dans l'environnement du siège (103).
7. Une méthode d'utilisation d'un outil de fond (101) dans un trou de sondage d'un puits de pétrole ou de gaz, l'outil de fond (101) possédant un siège (103) pour engager un dispositif d'activation (10,20,30,40), la méthode comprenant les étapes suivantes :
  - fourniture d'un dispositif d'activation (10,20,30,40) adapté pour passer à travers au moins une partie du trou de sondage et engager le siège (103), le dispositif d'activation (10,20,30,40) comprenant une âme (14,24) et une couche extérieure (12,22) d'un matériau contenant l'âme (14,24), l'âme (14,24) étant composée d'un matériau plus sensible à l'érosion que le matériau de la couche extérieure (12,22), l'érosion de la couche extérieure (12,22) pour l'exposition de l'âme (14,24) durant plus longtemps que l'érosion ultérieure de l'âme (14,24) ;
  - transport du dispositif d'activation (10,20,30,40) dans un écoulement de fluide de forage traversant le trou de sondage d'un point d'insertion dans le trou de sondage jusqu'au siège (103)

- de l'outil de fond (101), le dispositif d'activation (10,20,30,40) engageant le siège (103) de l'outil de fond (101) ;  
 modification de l'état d'activation de l'outil de fond (101), lorsque le dispositif d'activation (10,20,30,40) s'engage avec le siège (103), et érosion d'au moins une partie du dispositif d'activation (10,20,30,40) avec du fluide de forage, jusqu'à ce que le dispositif d'activation (10,20,30,40) puisse passer à travers le siège (103).
8. Une méthode selon la revendication 7, comportant l'érosion du dispositif d'activation (10,20,30,40) par l'écoulement du fluide de forage par le dispositif d'activation (10,20,30,40), lorsque le dispositif d'activation (10,20,30,40) se trouve dans le siège (103) de l'outil de fond (101).
9. Une méthode selon la revendication 7 ou la revendication 8, dans laquelle le dispositif d'activation (10,20,30,40) subit une érosion après l'étape de modification de l'état d'activation de l'outil de fond (101).
10. Une méthode selon une quelconque des revendications 7 à 9, dans laquelle le dispositif d'activation érodé passe à travers le siège (103) et est refoulé hors de l'outil de fond (101) par le fluide de forage.
11. Une méthode selon une quelconque des revendications 7 à 10, dans laquelle le dispositif d'activation (10,20,30,40) subit une érosion pendant une période comprise entre 10 secondes et 20 minutes, lorsqu'il se trouve sur le siège (103).
12. Une méthode selon une quelconque des revendications 7 à 11, dans laquelle la vitesse du fluide de forage est comprise entre 5 et 45 mètres par seconde.
13. Une méthode selon une quelconque des revendications 7 à 12, dans laquelle l'état d'activation de l'outil de fond (101) est modifié une deuxième fois par un deuxième dispositif d'activation (10,20,30,40), cette méthode comprenant les étapes supplémentaires suivantes :
- fourniture d'un deuxième dispositif d'activation (10,20,30,40) adapté pour passer à travers au moins une partie du trou de sondage et engager le siège (103), le deuxième dispositif d'activation (10,20,30,40) comprenant une âme (14,24) et une couche extérieure (12,22) d'un matériau contenant l'âme (14,24), l'âme (14,24) étant composée d'un matériau plus sensible à l'érosion que le matériau de la couche extérieure (12,22), l'érosion de la couche extérieure (12,22) pour l'exposition de l'âme (14,24) durant

plus longtemps que l'érosion ultérieure de l'âme (14,24) ;  
 transport du deuxième dispositif d'activation (10,20,30,40) dans un écoulement de fluide de forage traversant le trou de sondage jusqu'au siège (103) de l'outil de fond (101), le deuxième dispositif d'activation (10,20,30,40) engageant le siège (103) de l'outil de fond (101);  
 modification de l'état d'activation de l'outil de fond (101), lorsque le dispositif d'activation (10,20,30,40) engage le siège (103), et érosion d'au moins une partie du deuxième dispositif d'activation (10,20,30,40) avec du fluide de forage, jusqu'à ce que le deuxième dispositif d'activation (10,20,30,40) puisse passer à travers par le siège (103).

Figure 1.

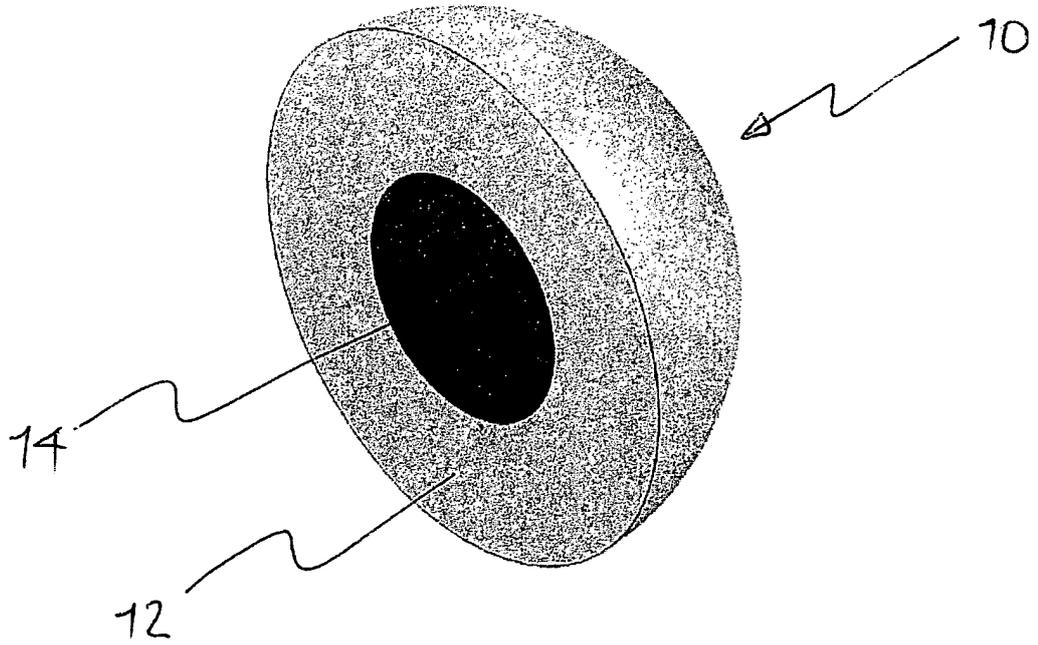
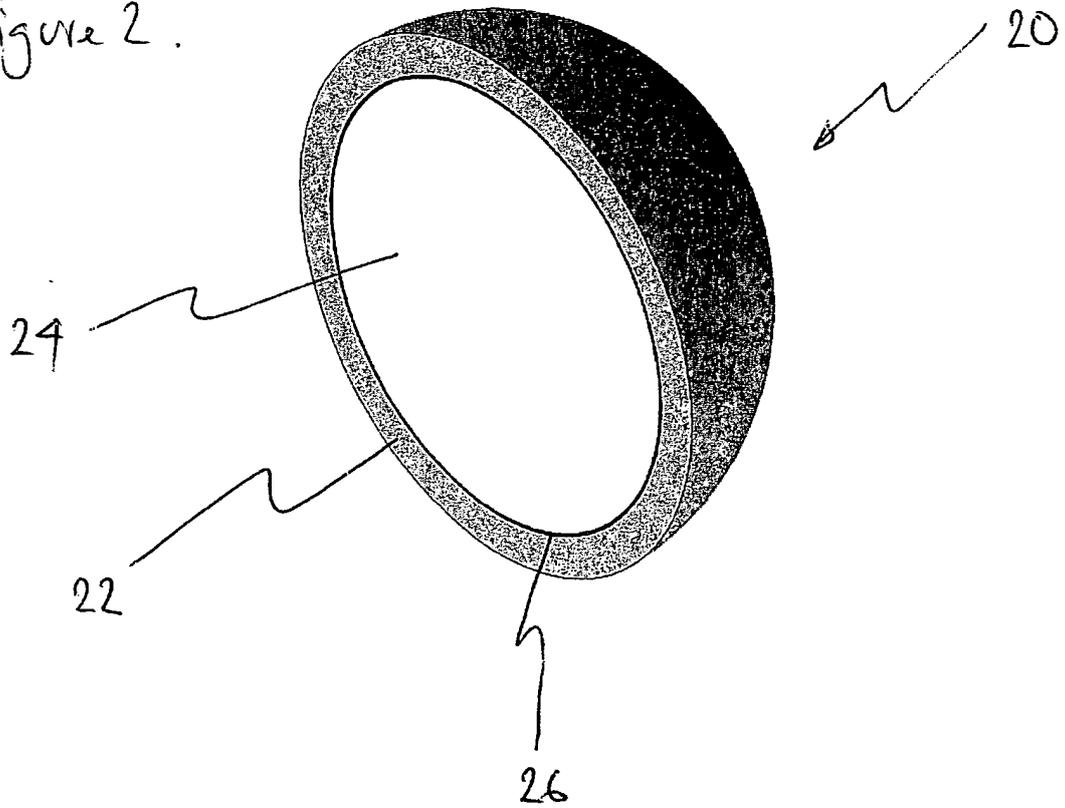


Figure 2.



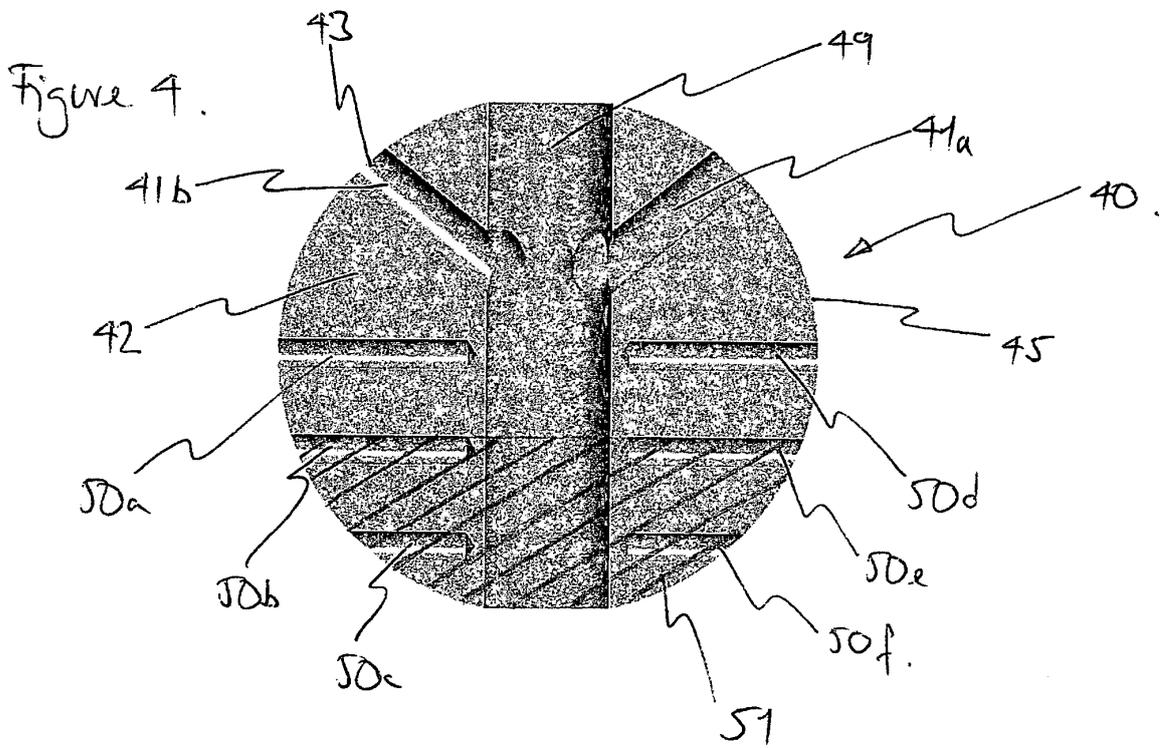
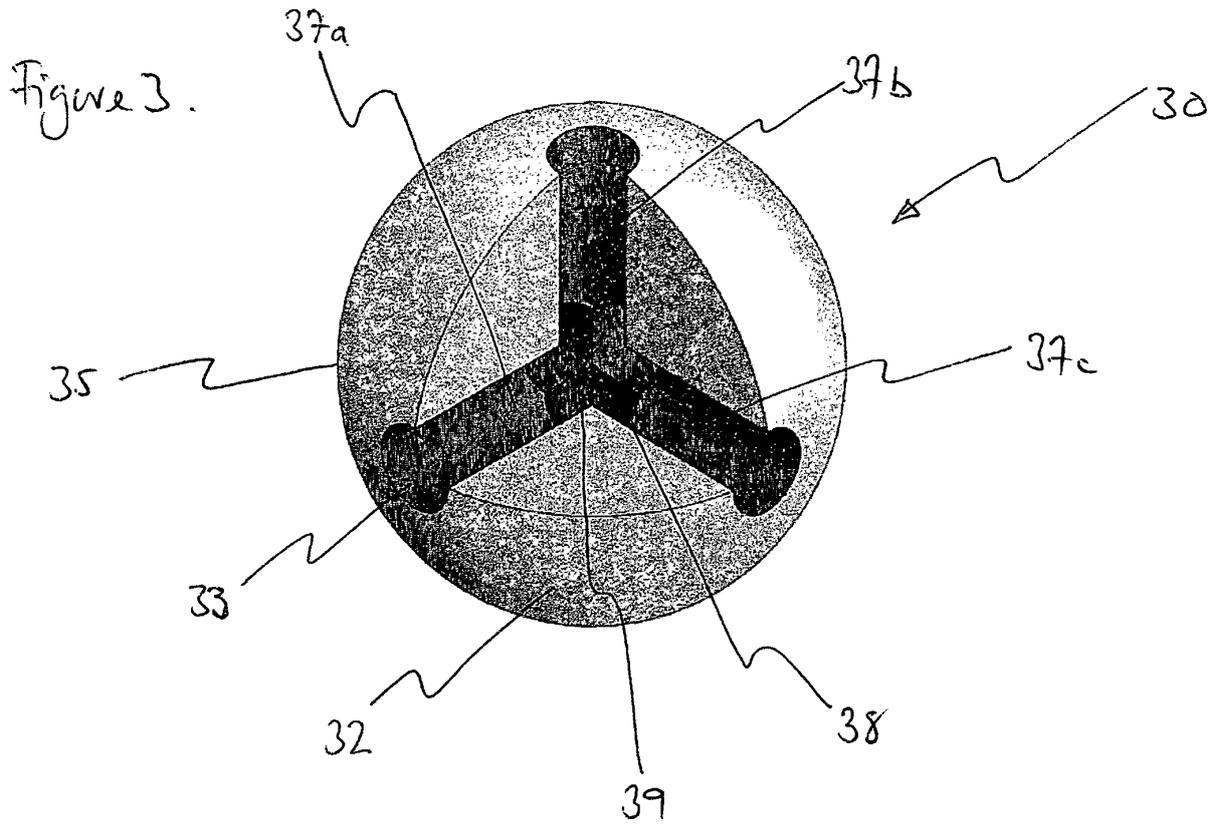


Figure 5.

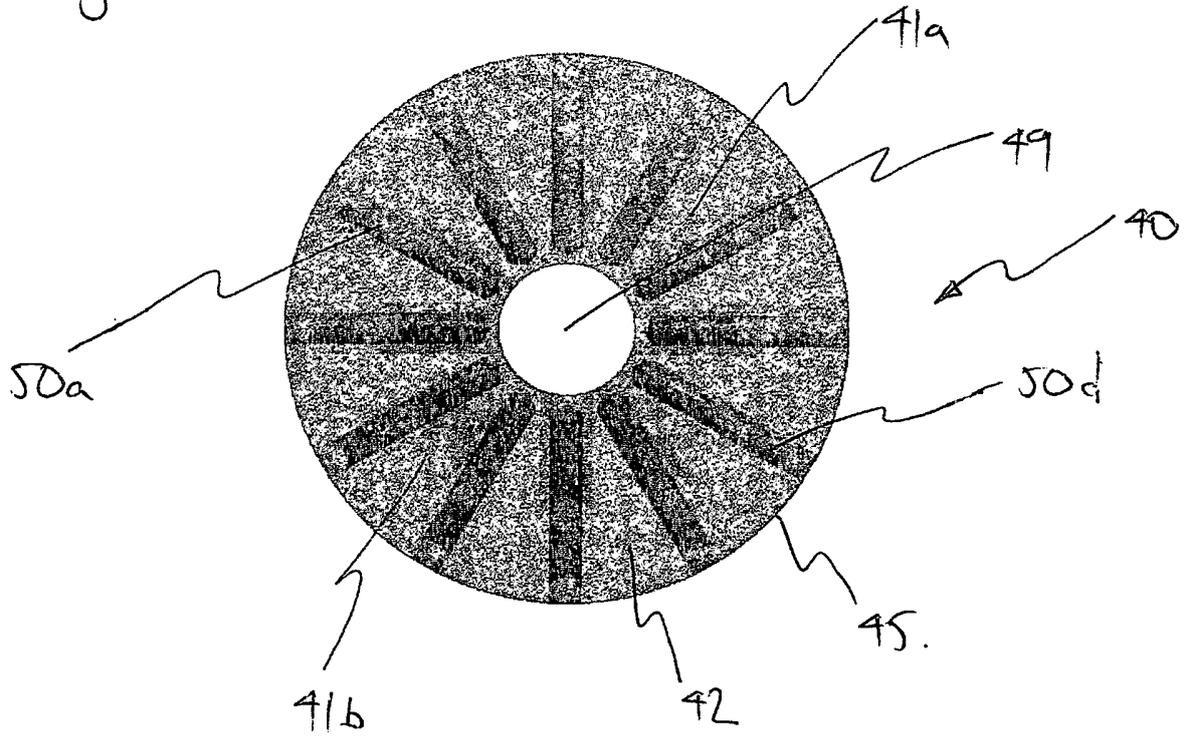


Figure 6.

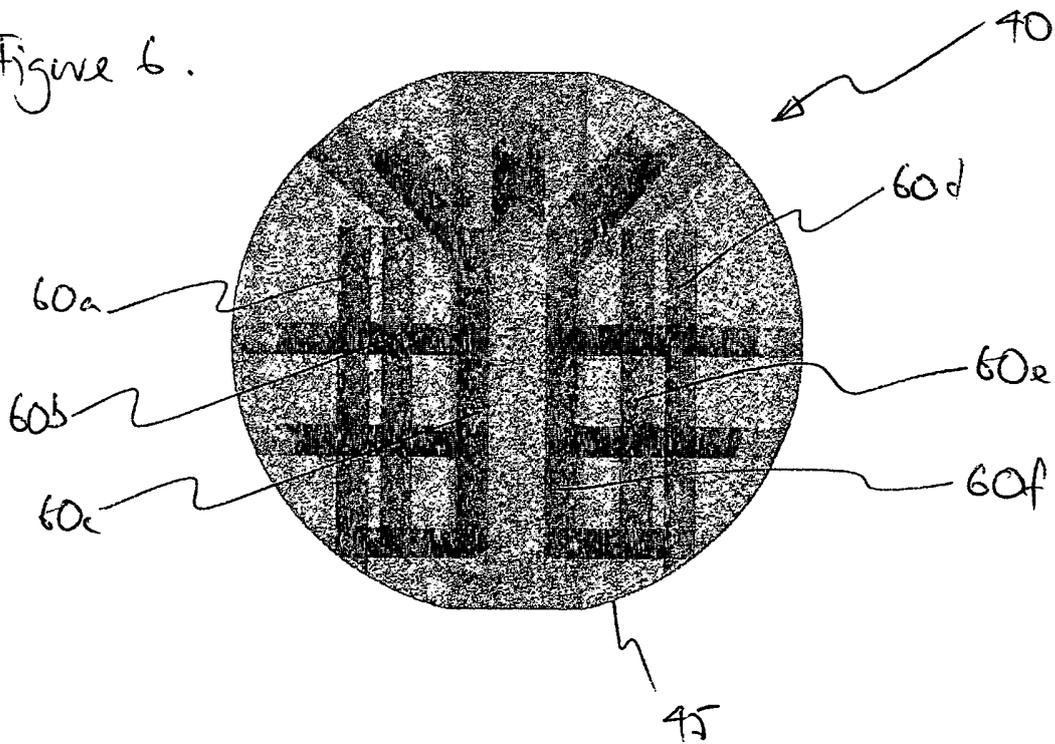


Figure 7.

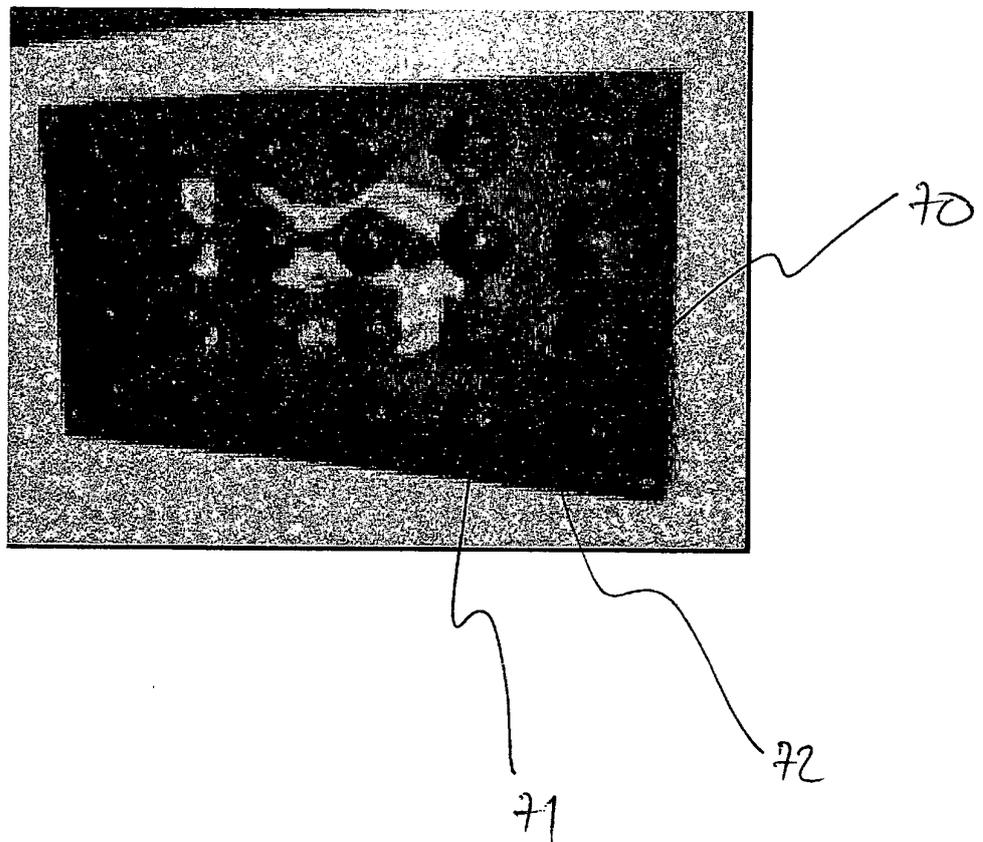


Figure 8.

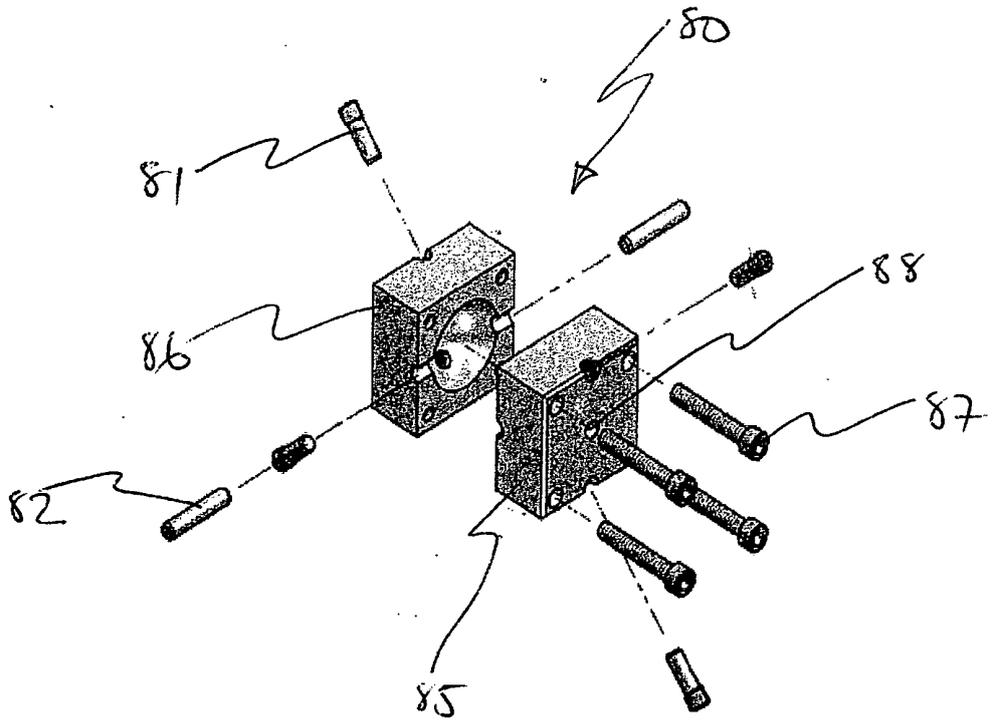


Figure 9.

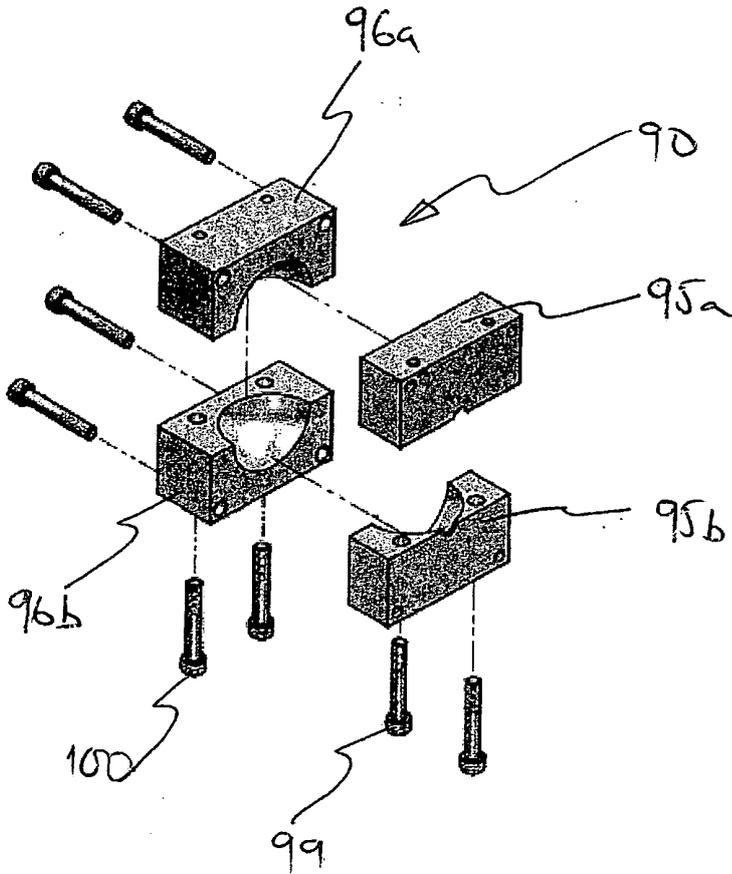
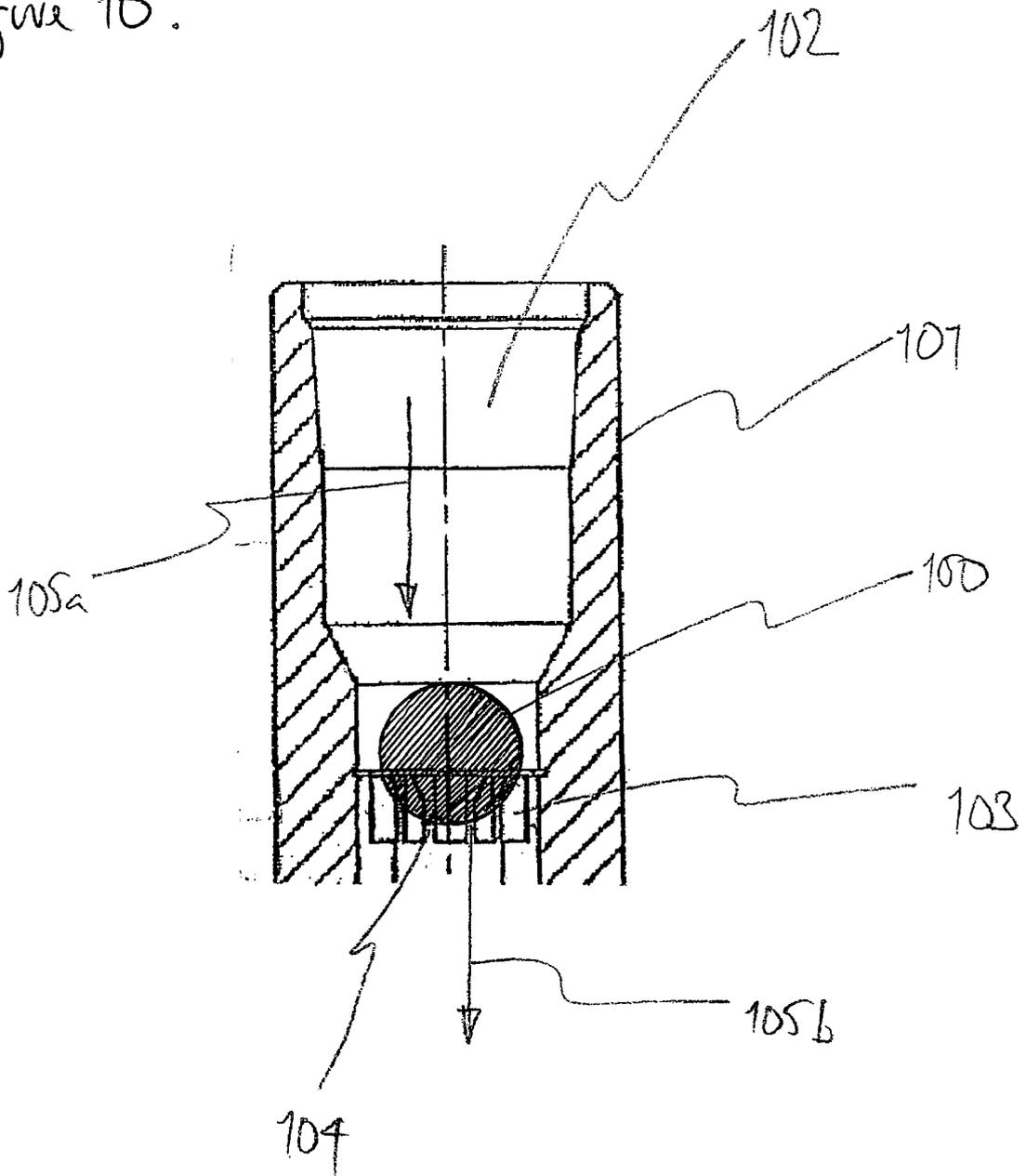


Figure 10.



**REFERENCES CITED IN THE DESCRIPTION**

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**Patent documents cited in the description**

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