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(54) **PRESSURE ACTIVATED LOCKING SLOT ASSEMBLY**

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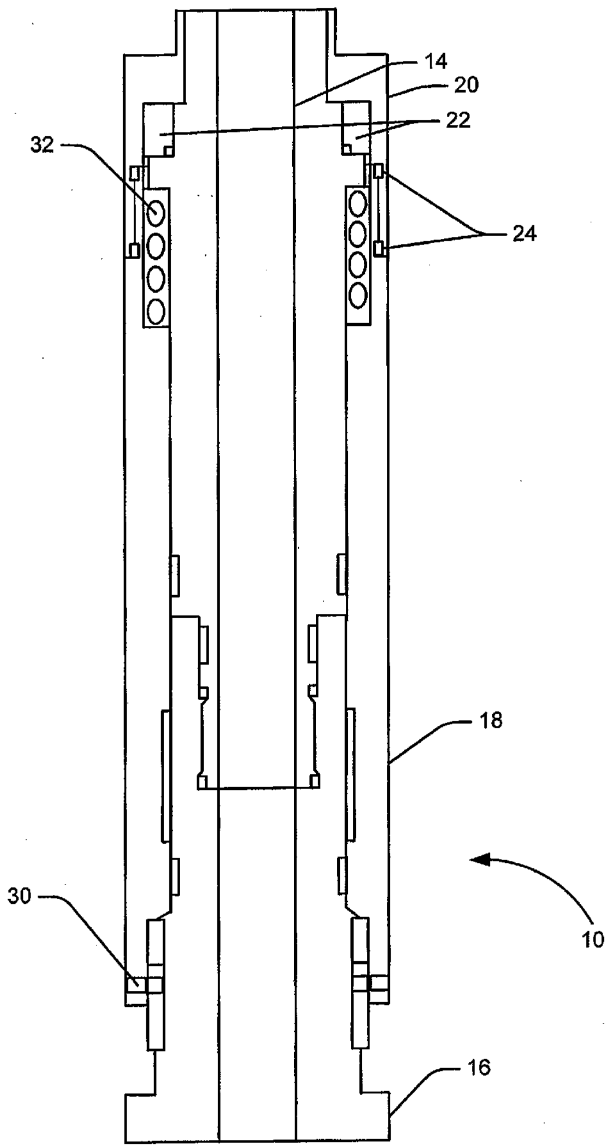
(57) **ABSTRACT**

A locking slot assembly may include a slot, a lug configured to move within the slot, and a lock configured to prevent the lug from moving within the slot until a triggering event occurs. The lock may be further configured to allow the lug to move within the slot after the triggering event has occurred, so long as a predetermined condition is maintained. The triggering event may be the application of a predetermined pressure, and the predetermined condition may be a minimum pressure.



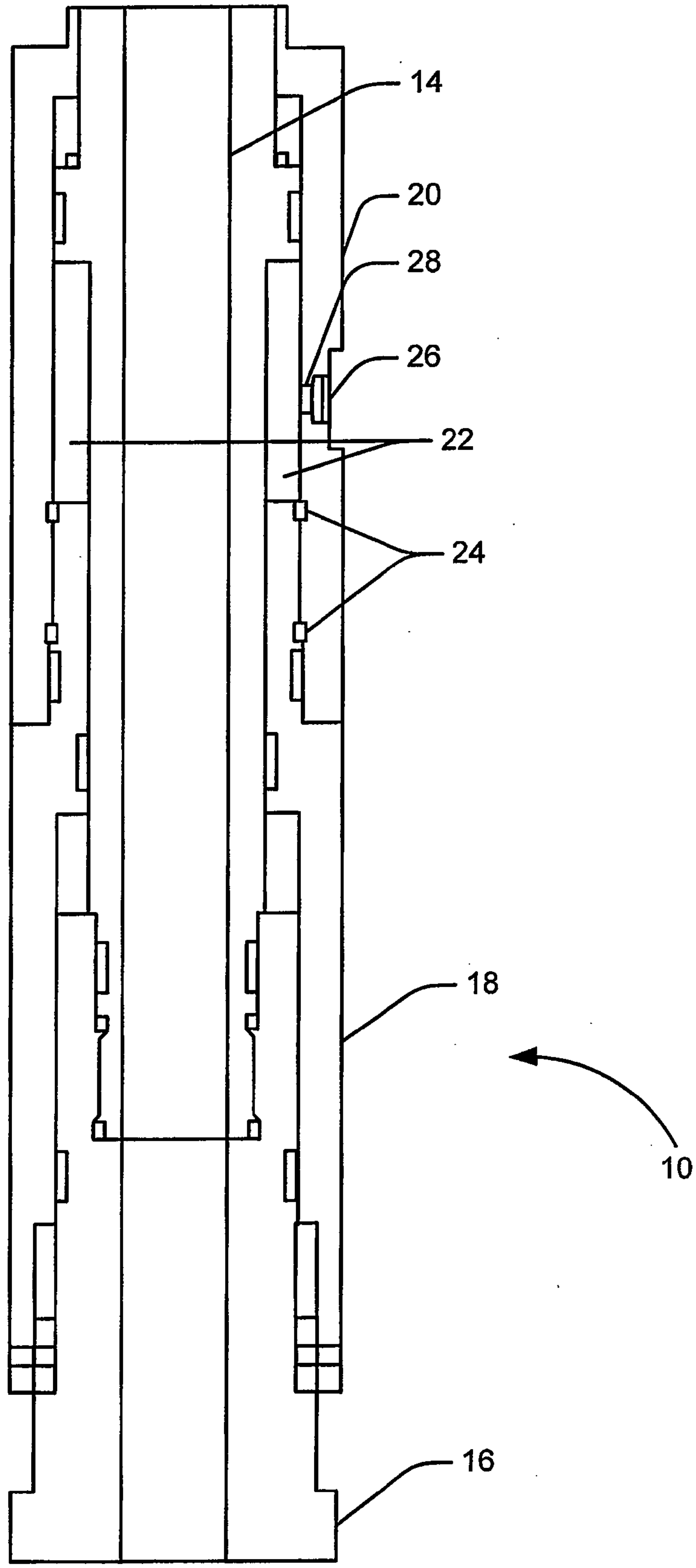


FIG. 1A

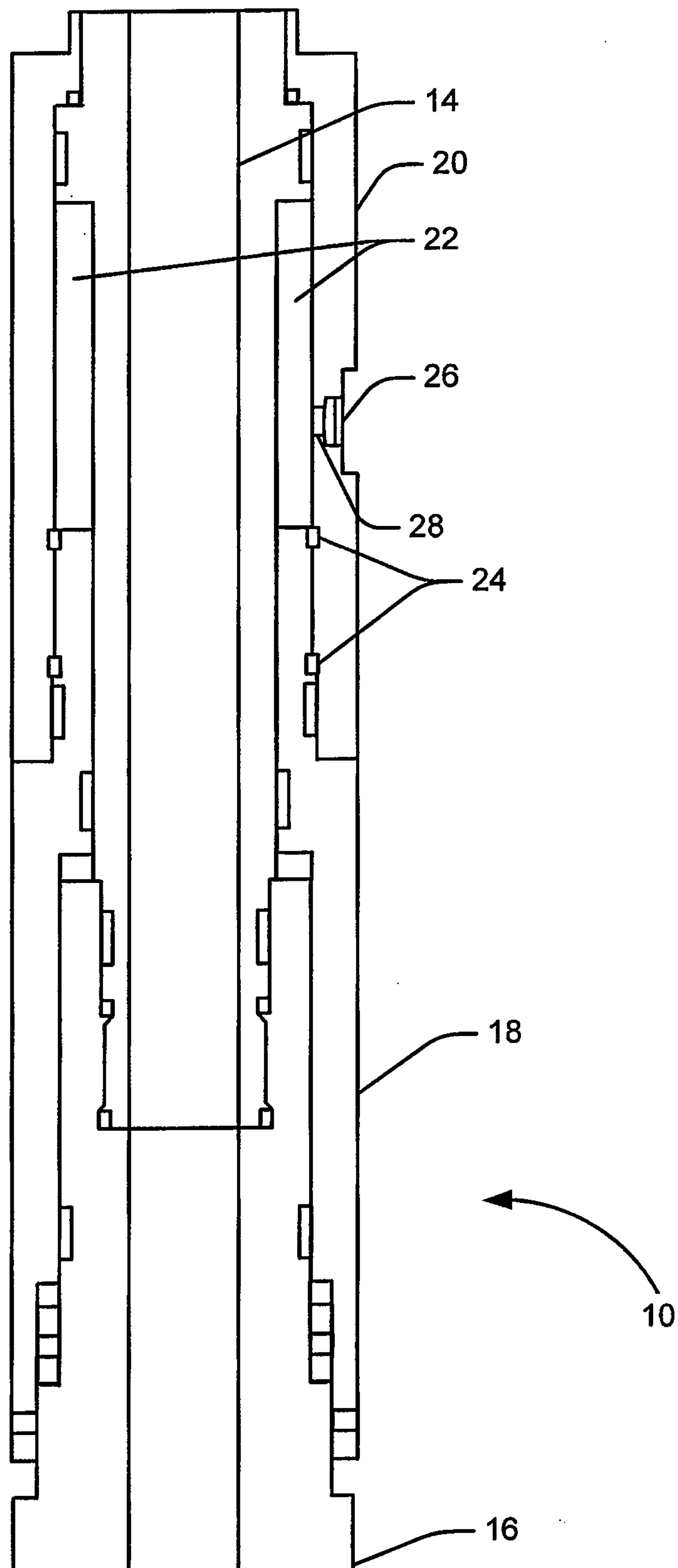


FIG. 1B

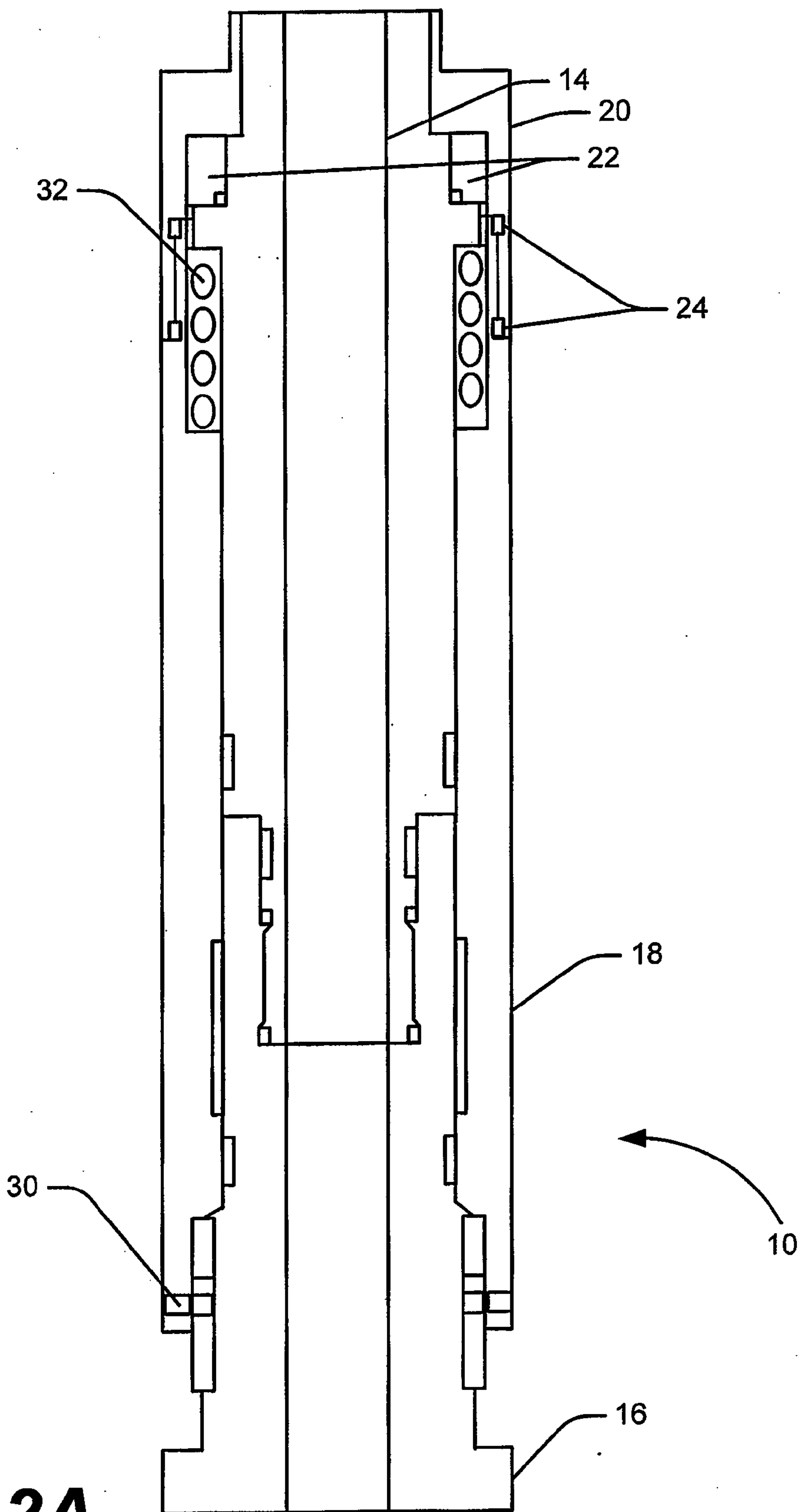


FIG. 2A

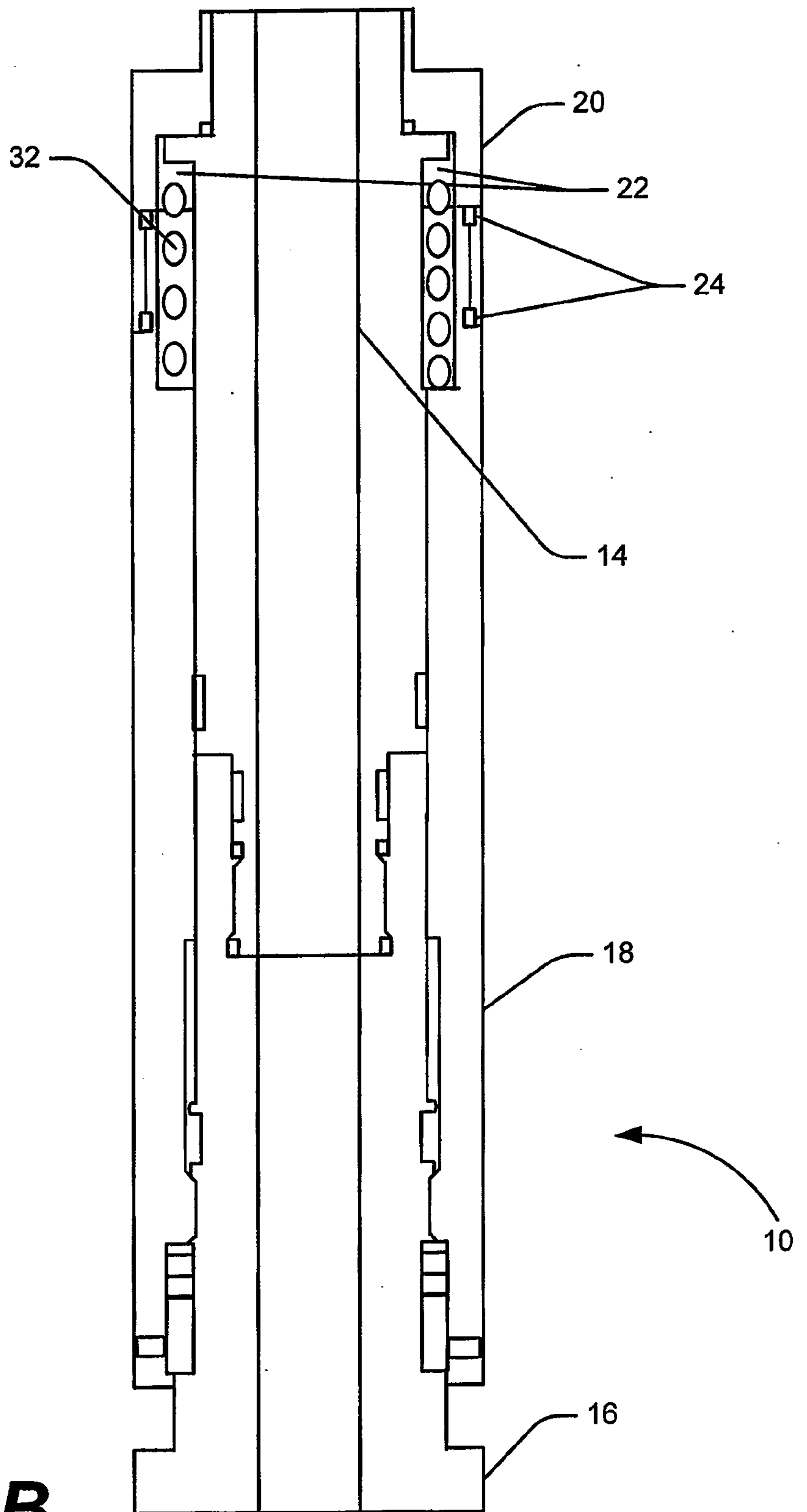


FIG. 2B

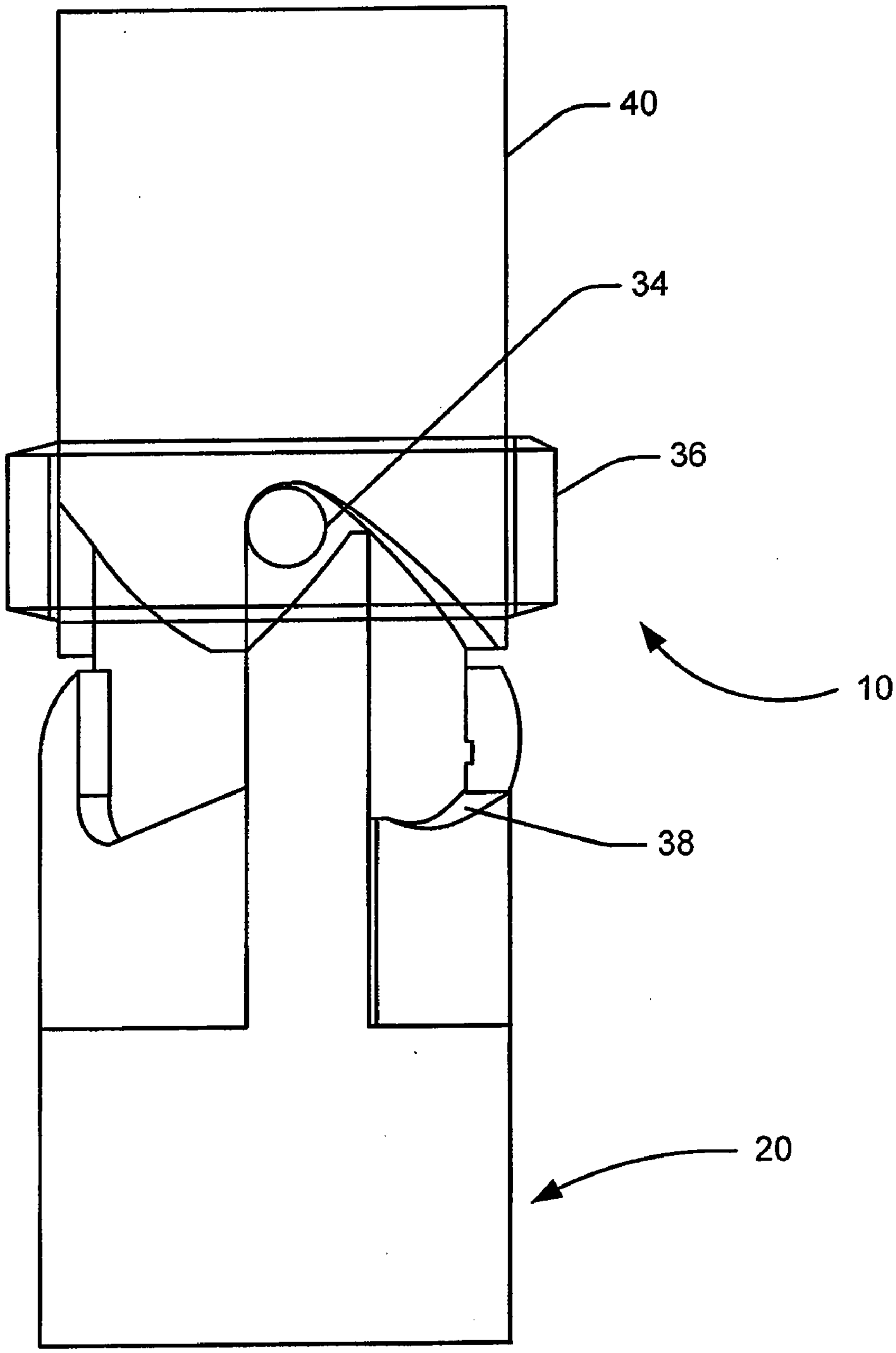


FIG. 3A

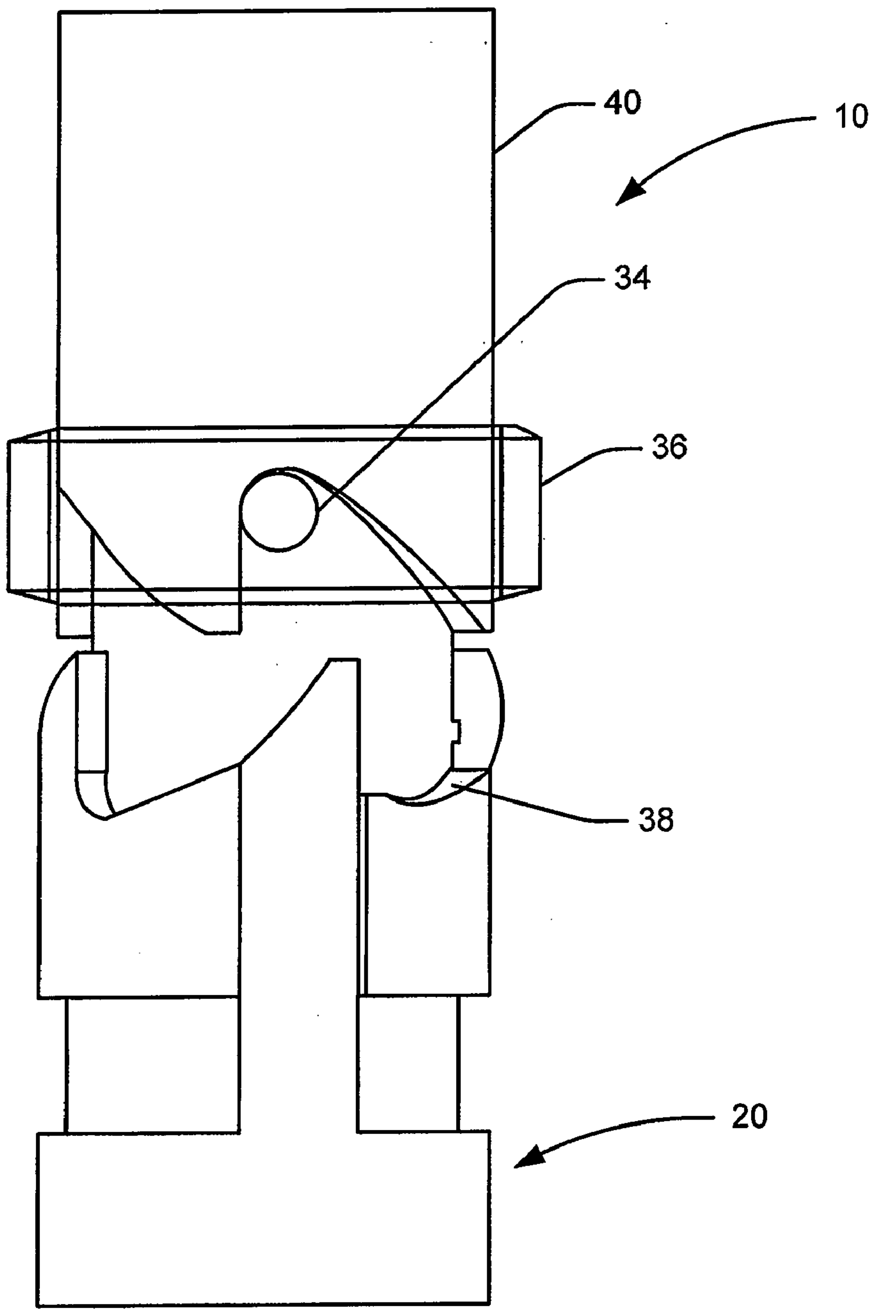


FIG. 3B

PRESSURE ACTIVATED LOCKING SLOT ASSEMBLY

BACKGROUND

[0001] The present invention relates to locking apparatus for downhole tools, and more particularly, to a pressure activated locking slot assembly.

[0002] Typically, when tools are run into the well bore, a mandrel is held in the run-in-hole position by interaction of a lug with a J-slot. To move the tool out of the run-in-hole position generally involves the application of torque and longitudinal force. Such an arrangement can be problematic in offshore or highly deviated sections of a well bore, where dragging forces on the tool string may create difficulty in estimating the proper torque to apply at the surface to obtain the desirable torque at the J-slot. A continuous J-slot wraps all the way around the mandrel and typically has two lugs, so that the direction of torque applied need not be reversed in order to actuate. Rather, the tool may simply be picked up and put back down to cycle.

[0003] A problem may arise when running such a tool into an offshore or highly deviated well bore. Dragging of the tool string on the well bore may cause the mandrel move relatively upwardly and rotate with respect to the drag block assembly sufficiently to result in premature actuation of the J-slot assembly. If such premature actuation occurs, subsequent downward load on the tool string may rupture the tool elements, or the tool elements may be damaged by dragging along the well bore. In addition, premature actuation may result in the tool string jamming in the well bore.

SUMMARY

[0004] The present invention relates to locking apparatus for downhole tools, and more particularly, to a pressure activated locking slot assembly.

[0005] In one embodiment of the present invention a locking slot assembly comprises: a slot; a lug configured to move within the slot; and a lock configured to prevent the lug from moving within the slot until a triggering event occurs; wherein the lock is further configured to allow the lug to move within the slot after the triggering event has occurred, so long as a predetermined condition is maintained. The triggering event may be the application of a predetermined pressure, and the predetermined condition may be a minimum pressure.

[0006] In another embodiment of the present invention a downhole tool assembly comprises: a sleeve having a slot; a lug rotator ring configured to move axially relative to the sleeve, the rotator ring having a lug configured to move within the slot; and a lock configured to prevent the lug from moving within the slot until a predetermined pressure is applied; and wherein the lock is further configured to allow the lug to move within the slot after the predetermined pressure has been applied, so long as a minimum pressure is maintained.

[0007] In yet another embodiment of the present invention a method of activating a downhole tool assembly comprises: providing a downhole tool assembly in a well bore; applying a predetermined pressure to the downhole tool assembly; and moving the downhole tool assembly upward; wherein the downhole tool assembly comprises a sleeve having a slot, a lug rotator ring configured to move axially relative to the sleeve, the rotator ring having a lug configured to move within the slot, and a lock configured to prevent the lug from moving within the slot until a predetermined pressure is applied.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] FIG. **1**A is a side cross-sectional view showing one embodiment according to the present invention.

[0009] FIG. **1**B is a side cross-sectional view of the embodiment illustrated in FIG. **1**A, showing an unlocked position.

[0010] FIG. **2**A is a side cross-sectional view showing another embodiment according to the present invention.

[0011] FIG. **2**B is a side cross-sectional view of the embodiment illustrated in FIG. **2**A, showing an unlocked position.

[0012] FIG. **3**A is a side view showing one embodiment according to the present invention.

[0013] FIG. **3**B is a side view of the embodiment illustrated in FIG. **3**A, showing an unlocked position.

DETAILED DESCRIPTION

[0014] Referring now to the drawings and more particularly to FIGS. **1**A and **1**B, the locking slot assembly of the present invention is shown and generally designated by the numeral **10**. locking slot assembly **10** is disposed adjacent to a lower end of a tool **12** (shown in FIG. **2**A), which is of a kind known in the art, such as a valve, a packer, or any tool requiring different positions. Tool **12** may connect to a tool string (not shown) and the entire tool string may be positioned in a well bore. The well bore may be defined by a casing (not shown) and may be vertical, or the well bore may be deviated to any degree.

[0015] Locking slot assembly **10** is illustrated below the tool **12**. Tool **12** may include, or be attached to, an inner, actuating mandrel **14**, which may be connected to the tool string. Locking slot assembly may include the actuating mandrel **14**, attached at a lower end to bottom adapter **16**. Actuating mandrel **14** and at least a portion of bottom adapter **16** may be situated within a fluid chamber case **18** and/or a lock **20**. The fluid chamber case **18** and the lock **20** may be removably attached, fixedly attached, or even integrally formed with one another. Alternatively fluid chamber case **18** and lock **20** may be separate.

[0016] At least one fluid chamber **22** may be situated between actuating mandrel **14** and lock **20**. Fluid chamber **22** may be sealed via one or more seals **24**, along with a rupture disk **26** situated in the lock **20**. Air at atmospheric pressure may initially fill the fluid chamber **22**. As the tool **12** is lowered into the well bore, hydrostatic pressure outside the tool **12** increases. Once the hydrostatic pressure reaches a predetermined value, the rupture disk **26** may rupture. After the rupture disk **26** has ruptured, the fluid outside the tool **12** will enter the tool **12** through a port **28** formed therein. The resulting increased pressure within the fluid chamber **22** will cause the fluid chamber **22** to expand (as shown in FIG. **1**B). This expansion causes the longitudinal movement of the lock **20** with respect to the actuating mandrel **14**, thus "unlocking" the locking slot assembly **10**. FIGS. **3**A and **3**B, which will be discussed below, further show the locked position and unlocked position respectively.

[0017] Referring now to FIGS. **2**A and **2**B, shown therein is an alternate embodiment of the locking slot assembly **10**. This embodiment has no rupture disk **26**. Instead, one or more shear pins **30** to prevent the lock **20** from moving until adequate pressure is present. A spring **32** may be included to keep the locking slot assembly **10** in an unlocked position. While the spring **32** shown is a coil spring, the spring **32** may be any biasing member. Likewise, the shear pin **30** may be a screw, spring, or any other shearable member. Other than the use of a rupture disk **26** and/or a spring **32**, the embodiment of FIGS. **2**A and **2**B functions similarly to the embodiment of FIGS. **1**A and **1**B. An increase in pressure causes the lock **20** to move longitudinally with respect to the actuating mandrel **14**, resulting in the unlocking of the locking slot assembly **10** (as shown in FIG. **2**B).

[0018] Referring now to FIGS. **3**A and **3**B, one or more lugs **34** may extend from a lug rotator ring **36** into a continuous slot **38** in a sleeve **40**, thus providing locking assembly **10**. As previously discussed, pressure may cause the lock **20** to become unlocked. In the locked position, a locking portion **42** of the lock **20** occupies space within the slot **38**, keeping the lugs **34** in a run-in-hole position, and preventing the lugs **34** from moving relative to the slot **38**. As the lock **20** moves downwardly because of increased pressure, the locking portion **42** moves out of the slot **38**, allowing the lugs **34** to move relative to the slot **38** if there is an upward or downward force acting on the sleeve **40**.

[0019] In the run-in-hole, locked position, the lock **20** is in an upward position, in which lugs **34** are engaged with locking portion **42** of the lock **20**. As the tool string is lowered into well bore, the locking slot assembly **10** will remain in the locked position shown in FIGS. **1**A, **2**A, and **3**A, with the lock **20** preventing relative longitudinal movement of the lug rotator ring **36** with respect to the sleeve **40**.

[0020] Once pressure is applied and the locking slot assembly **10** is unlocked (as shown in FIGS. **1**B, **2**B, and **3**B), the locking slot assembly **10** may be actuated, allowing the lug rotator ring **36** to move longitudinally with respect to the sleeve **40**. In other words, the tool **12** may be set by pushing downward on the tool string, which lowers lug **34**. While any type of slot **38** may be used, the embodiment shown uses a j-slot, and in particular, shows a continuous J-slot. Depending on the specific application and the type of slot, setting the tool may involve pushing downward on the tool string multiple times. Thus, when a continuous j-slot is used, the tool **12** may be set by up and down motion alone. This may prevent the operator from cycling through the slot and setting the tool **12** prematurely.

[0021] For retrieval, the tool string is simply pulled upwardly out of the well bore. This will cause the lug **34** to re-engage the slot **38**. Additionally, as the pressure outside the tool **12**, and thus, the pressure within the fluid chamber **22** is reduced, the lock **20** may move back into the locked position, preventing any subsequent relative movement of the lug rotator ring **36** with respect to the sleeve **40**.

[0022] While the application of pressure is disclosed above as one triggering event to allow the lug **34** to move within the slot **38**, other events may also occur to allow the lug **34** to move within the slot **38**. In this case, the lock **20** may be configured to allow the lug **34** to move within the slot after the triggering event has occurred, so long as a predetermined condition is maintained. For example, but not by way of limitation, the triggering event may be a timer reaching a predetermined value, and the predetermined condition may be that the timer has not yet reached a second predetermined value.

[0023] Therefore, the present invention is well adapted to attain the ends and advantages mentioned as well as those that are inherent therein. The particular embodiments disclosed above are illustrative only, as the present invention may be modified and practiced in different but equivalent manners apparent to those skilled in the art having the benefit of the teachings herein. Furthermore, no limitations are intended to the details of construction or design herein shown, other than as described in the claims below. It is therefore evident that the particular illustrative embodiments disclosed above may be altered or modified and all such variations are considered within the scope and spirit of the present invention. Also, the terms in the claims have their plain, ordinary meaning unless otherwise explicitly and clearly defined by the patentee.

What is claimed is:

1. A locking slot assembly comprising:

a slot;

a lug configured to move within the slot; and

a lock configured to prevent the lug from moving within the slot until a triggering event occurs;

wherein the lock is further configured to allow the lug to move within the slot after the triggering event has occurred, so long as a predetermined condition is maintained.

2. The locking slot assembly of claim **1**, wherein the triggering event is the application of a predetermined pressure, and wherein the predetermined condition is a minimum pressure.

3. The locking slot assembly of claim **2**, further comprising:

an inner mandrel disposed at least partially within the lock; and

a fluid chamber disposed between the lock and the inner mandrel;

wherein the fluid chamber is configured to expand upon application of the predetermined pressure, moving the lock and allowing the lug to move within the slot.

4. The locking slot assembly of claim **2**, wherein the slot comprises a J-slot.

5. The locking slot assembly of claim **4**, wherein the J-slot is a continuous J-slot.

6. The locking slot assembly of claim **2**, wherein the lock comprises one or more rupture disks configured to rupture at the predetermined pressure, allowing the lug to move within the slot.

7. The locking slot assembly of claim **2**, wherein the lock comprises one or more shear pins configured to shear at the predetermined pressure, allowing the lug to move within the slot.

8. The locking slot assembly of claim **2**, wherein the lock is further configured to once again prevent the lug from moving within the slot if the minimum pressure is not maintained.

9. The locking slot assembly of claim **2**, wherein the predetermined pressure is a hydrostatic pressure.

10. The locking slot assembly of claim **2**, wherein the minimum pressure is a hydrostatic pressure.

11. A downhole tool assembly comprising:

a sleeve having a slot;

a lug rotator ring configured to move axially relative to the sleeve, the rotator ring having a lug configured to move within the slot; and

a lock configured to prevent the lug from moving within the slot until a predetermined pressure is applied; and wherein the lock is further configured to allow the lug to move within the slot after the predetermined pressure has been applied, so long as a minimum pressure is maintained.

12. The downhole tool assembly of claim **11**, further comprising:

an inner mandrel disposed at least partially within the lock; and

a fluid chamber disposed between the lock and the inner mandrel;

wherein the fluid chamber is configured to expand upon application of the predetermined pressure, moving the lock and allowing the lug to move within the slot.

13. The downhole assembly of claim **1 1**, wherein the slot comprises a J-slot.

14. The downhole assembly of claim **12**, wherein the J-slot is a continuous J-slot.

15. The downhole assembly of claim **11**, wherein the lock comprises one or more rupture disks configured to rupture at the predetermined pressure, allowing the lug to move within the slot.

16. The downhole assembly of claim **11**, wherein the lock comprises one or more shear pins configured to shear at the predetermined pressure, allowing the lug to move within the slot.

17. The downhole assembly of claim **11**, wherein the lock is further configured to once again prevent the lug from moving within the slot if the minimum pressure is not maintained.

18. The downhole assembly of claim **1 1**, wherein the predetermined pressure is a hydrostatic pressure.

19. A method of activating downhole tool assembly comprising a sleeve having a slot, a lug rotator ring configured to move axially relative to the sleeve, the rotator ring having a lug configured to move within the slot, and a lock configured to prevent the lug from moving within the slot until a predetermined pressure is applied, the method comprising:

providing a downhole tool assembly in a well bore;

applying a predetermined pressure to the downhole tool assembly; and

moving the downhole tool assembly upward.

20. The method of activating a downhole tool assembly of claim **19**, further comprising:

moving the downhole tool assembly downward.

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