1274693

PATENT SPECIFICATION (11) 1274693

DRAWINGS ATTACHED

(21) Application No. 49463/69 (22) Filed 8 Oct. 1969
(31) Convention Application No. 769 776 (32) Filed 23 Oct. 1968 in
(33) United States of America (US)
(45) Complete Specification published 17 May 1972
(51) International Classification E21B 33/04
(52) Index at acceptance E1F 44
(72) Inventor KELLY VERNER SHIPES

(54) IMPROVEMENTS IN OR RELATING TO WELL TOOLS

(71) We, FMC CORPORATION, a corporation organized and existing under the laws of the State of Delaware, United States of America, of 1105 Coleman Avenue, San Jose, California, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:

This invention relates to well tools for sealing or packing off the annular-section space between the well bore and the casing at the well head.

In the process of drilling a well for petroleum or other fluids, the hole or bore normally is lined with pipe to prevent it from caving, preclude migration of fluids from one earth stratum to another, and avoid erosion of the bore surface by the fluids used in drilling as well as the petroleum or other fluids that are ultimately produced. This lining, called the casing, is suspended or hung from a casing head at the top of the well, and is secured at its lower end to the well bore by cement. For one reason or another, practically all wells are lined with two or more concentric strings of casing, the outermost or surface casing extending perhaps but a few hundred feet and the inner string or strings extending consecutively further. Each of these casing strings must be sealed fluid-tight to the casing head, and to accomplish this a well tool, called a packoff and having one or more seal rings of rubber or other resiliently deformable material is positioned or set in the head surrounding the string and then forced axially by tightening a series of lockdown screws until the seal rings exert a pressure against the head and casing higher than that of the fluid to be contained.

Although the prior art is replete with various packoffs, including some that might function quite satisfactorily where well pressures of average magnitude are involved, the pressures encountered in the deep wells now being drilled often are so high, such as 10,000 psi or more, as to be beyond the sealing capabilities of the previously proposed devices. The ability to generate adequate force on the packoff by means of the lockdown screws is limited, and attempting to exceed this limit in order to control these higher pressures by further turning the screws merely embeds them in the packoff or destroys them.

According to the present invention there is provided a well tool, comprising an annular primary body portion, an annular secondary body portion axially spaced from said primary body portion, a resiliently deformable seal ring disposed between said primary and secondary body portions, a junk ring intermediate said seal ring and one of said body portions, and a pressure-responsive piston associated with said junk ring and extending freely through a passage in said seal ring, the arrangement being such that force exterted on said piston and said junk ring is transferred to said seal ring in an amount per unit area higher than the force per unit area exerted on said piston and said junk ring.

Further, according to the present invention, there is provided a well tool for packing off an annular-section space between a well head and an inner concentric pipe string, comprising an annular primary body portion, an annular secondary body portion coaxial with and spaced from said primary body portion, a first resiliently deformable seal ring intermediate said primary and secondary body portions, a second resiliently deformable seal ring intermediate said first seal ring and said secondary body portion, a pair of junk rings intermediate said seal rings, and a plurality of pistons each of which is associated with a said junk ring and extends freely through a respective passage in a said seal ring, said pistons, said junk rings, and said seal rings being so interassociated that when said pistons and junk rings are pressed toward said seal rings, said seal rings are subjected to a force higher per unit area than that exerted on said pistons and said junk rings.

Yet further according to the present invention, there is provided a well tool for packing off an annular-section space between a well head and a well string, comprising an annular

[Price 25p]

rigid support element having inner and outer radially spaced surfaces, said support element having at least one axial bore intermediate its inner and outer radially spaced surfaces, a resiliently deformable seal ring having inner and outer radially spaced surfaces, and at least one axial bore intermediate its said inner and outer radially spaced surfaces, an axial end surface of the seal ring facing one axial end surface of the support element, and a piston extending into the respective bores in the support element and the seal ring and retained therein, the arrangement being such that, when the tool is in position in the said annular-section space and a pressure at a first force per unit area is exerted axially against the other axial end surface of the support element and an axial end surface of the piston, the said one axial end surface of the support element transmits said pressure to the end surface of the seal ring at a second force per unit area greater than said first force per unit area.

From another aspect according to the present invention, there is provided a method of packing an annular-section space between a well casing head and a tubular well string surrounded thereby, comprising the steps of installing a resiliently deformable seal ring and a rigid annular support element in the annular-section space circumscribing the well string, a pressure-responsive piston associated with the support element extending freely through a passage in the seal ring, axially compressing the seal ring so that it establishes a primary fluid-tight seal between the well string and casing head, applying an axial force against the support element and the piston to bias the support element against the seal ring, and transmitting the force to the seal ring at a force per unit area greater than the force per unit area applied against the support element and piston.

An embodiment of the invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a perspective view of a well tool or packoff in accordance with the invention, with a portion of the packoff broken away to show the arrangement of the parts more clearly;

Figure 2 is a diametrical section through the packoff of Figure 1, installed between a casing head and casing string with lockdown screws applying sufficient force to establish an intial seal between seal rings, a casing head, and a casing string;

Figure 3 is a fragmentary view, to an enlarged scale, of the right-hand portion of Figure 2; and

Figure 4 is a view like Figure 3, but showing the condition of the packoff when both sealrings are compressed.

Broadly considered, and with reference to the drawings, a preferred embodiment of this invention comprises a packoff 10 with a primary or upper body portion 12, a secondary or lower body portion 14, a pair of rubber or otherwise resiliently deformable seal rings 16, 18 adjacent the body portions 12, 14 respectively, a pair of annular support elements in the form of rigid junk rings 20, 22 intermediate the seal rings 16, 18 a number of pin-like pistons 24 extending through axial bores or other passages in the junk ring 20 and freely through respective axial bores or other passages in the seal ring 16, and an equal number of pin-like pistons 26 extending from the junk ring 22 freely through respective axial bores or other passages in the seal ring 18. The passages in the seal rings 16, 18 and in the junk rings 20, 22 are intermediate the inner and outer radially spaced surfaces thereof. These elements are held together in their illustrated assembled relationship by a plurality of circumferentially spaced cap-screws 28 that slidably extend through aligned holes in the lower body portion 14, the seal rings 16, 18 and the junk rings 20, 22, into threaded engagement with the upper body portion 12.

The packoff's upper body 12 has an external annular groove 29 with a lower surface 30 that provides a bearing for lockdown screws 32 (Figs. 2, 3 and 4) that extend through the side wall of the well casing head 34 to hold the packoff in the casing head. A lateral port 36 extends through the upper body 12 between the groove 28 and the packoff's bore 38, and another port 40 extends through the casing head 34, to provide fluid communication between the interior of the packoff and the outside of the casing head, such as for circulation of well drilling fluid.

When the packoff 10 is in place in a casing head such as 34 (Fig. 2), it surrounds the top of a casing string 42 that is hung in the usual manner in the casing head by a hanger 44 with slips 46. The packoff's lower body portion 14 rests upon the hanger 44, so that when the lockdown screws 32 are threaded inwardly, thereby applying a downward force on the packoff, the seal rings 16, 18 are compressed and are deformed outwardly into tight engagement with the casing head 34 and the casing 42, establishing a fluid-tight seal therebetween, such a seal being capable of withstanding relatively low pressures only, for example about 500 psi. This is the condition, indicated in Figures 2 and 3, that is established prior to subjecting the packoff 10 to greater pressures sufficient to activate its self-energizing function.

The pistons 24 extend through the upper junk ring 20 and the seal ring 16 into bores 48 in the packoff's upper body 12, and in like manner the pistons 26 extend in the opposite direction through lower junk ring 22 and the lower seal ring 18 into bores 50 in the packoff's lower body 14. The pistons 24 preferably are spaced uniformly around the packoff, thereby distributing their effect evenly, and in

similar fashion the pistons 26 are spaced directly opposite the pistons 24. The opposed axial end surfaces of the pistons 24, 26 are diametrically enlarged to provide flange-like heads 24a, 26a, respectively, and these heads are countersunk into the junk rings 22, 20, so that they do not conflict when the junk rings are abutting (Figs. 1-3). When the junk rings 20, 22 have substantially the same outer and inner diameters, respectively, as those of the seal rings 16, 18 such as is illustrated in the drawings, there is a significant difference between the size of the annular area made up of a junk ring and its pistons compared with the area of the seal ring against which the junk ring abuts, and this difference is the sum of the cross-sectional area of the pistons. Pressure acting on a piston exerts an axial force proportional to the cross-sectional area of the piston body, which force is transferred to the junk ring by means of the piston retaining flange. Since this axial force is transferred from the junk ring to the seal ring, the force per unit area, or pressure at the junk ring-seal ring interface, and hence the pressure exerted by the seal rings against the casing head 34 and the casing 42, is significantly greater than the pressure applied to the piston and junk ring.

In other words, when an axial force towards the seal rings is applied to the junk rings and their pistons, this force will not be increased, but will be opposed by an equal and opposite axial force exerted by the seal rings on the junk rings. However, since the axial end surface of the seal rings that receives this force is less in area size, by virtue of the piston area, than the axial end area of the junk rings and their pistons, the force per unit area (or pressure) on the seal rings is greater than the force per unit area (or pressure) which generates the axial force on the junk rings and their pistons. Thus, it can be said that a truly "self-energizing" action is achieved by the junk ring-pistons-seal ring assembly.

Figure 4 illustrates the effect on the packoff 10 when a pressure P1 is introduced through the casing head 34 via a lateral port 52, as is commonly done in testing after the packoff is set in the casing head. The pressure P1, of course, acts equally on both junk rings 20, 22 in an axial direction towards the seal rings 16, 18 and likewise on the pistons 24, 26, forcing the junk rings and their pistons apart axially, and thereby compressing and deforming the seal rings into tighter engagement with the casing head 34 and the casing string 42. If, for example, the effective exposed axial end surface area of the junk rings 20, 22 and the heads 24a, 26a of the pistons 24, 26, were 104 square inches, and the resisting surface area of the seal rings were 95 square inches, the resultant seal ring pressure would be greater than the applied pressure P1 by a factor of 104/95, or 1.095/1. This has been found to be a highly effective ratio for very high well pressures. However, it should be understood that other ratios are also within the scope of this invention, dependent among other things upon the nature of the composition of the seal rings, the size of the packoff, and the well pressure which is to be controlled. Lower ratios, such as 1.05 to 1, also have been found quite satisfactory for certain conditions.

The "self-energizing" action works equally well if axial pressure is applied to just one of the junk rings, i.e., in either a downward direction as P2 (Fig. 4) against the junk ring 22 and pistons 26, or an upward direction as P3 against the junk ring 20 and its pistons 24. In the case of pressure P2, the seal ring 16 derives no benefit from the pistons 24 since the pressure P2 would also be exerted against the pistons' end faces 24b through port 54 to equalize the pressure exerted against the heads 24a. However, since pistons 26 would be exposed to the pressure P2 only at their heads 26a, the pistons 26, the junk ring 22, and the seal ring 18 would respond to this pressure in the same way as they respond to the pressure P1. Hence, under the influence of the pressure P2 the seal ring 18 will deform as represented in Figure 4 to establish a fluid-tight barrier between the casing head 34 and the casing 42, thereby preventing the pressure P2 from passing by the packoff 10.

In the same manner, when a pressure P3 (Fig. 4) is applied in an axially upward direction, such as a pressure in the annulus between the casing head 34 and the casing 42, the seal ring 18 would derive no benefit from the pistons 26 since the pressure P3 is exerted equally against the piston heads 26a and their opposite axial end surfaces 26b, whereas the seal ring 16 is self-energised just as when the the pressure P1 is applied thereto. This results in a fluid-tight carrier between the casing head 34 and the casing 42 at the seal ring 16 to effectively contain the pressure P3 below the seal ring 16. As will be apparent, it has been assumed that the pressures P2 and P3 are higher than the maximum pressure capable of being withstood by the seal produced due to the force exerted by the lockdown screws alone.

Among the several advantages of this embodiment is that of the force required of the lockdown screw to set the packoff in the casing head, it being necessary only to apply enough initial force to effect a pressure differential across the seal rings 16, 18. In fact, a force of as little as 500 psi, or as low as five percent of that normally required with other packoffs, has been found to be quite adequate to set the packoff herein disclosed. This in turn substantially eliminates the extensive deformation of the packoff shoulders which occurs when the lockdown screws must be turned in to generate seal pressure greater than the liquid to be contained.

Since the piston can move freely in an axial direction with respect to the seal rings, when pressure is applied against the junk rings and the pistons in an axial direction tending to compress the seal rings between the junk rings and the body portions, this pressure is opposed by a seal ring surface of less area than the surface against which the pressure is applied, and the seal rings exert a proportionately greater pressure against the casing head and the casing. Hence, when the applied pressure is that of the well itself, the seal rings establish a fluid-tight barrier regardless of the pressure magnitude.

Furthermore, once the seal is established, any increase in well pressure will act through the junk-piston-seal ring combination to proportionately increase the sealing pressure, thereby assuring that the seal between the casing head and the casing remains intact.

WHAT WE CLAIM IS:—

1. A well tool, comprising an annular primary body portion, an annular secondary body portion axially spaced from said primary body portion, a resiliently deformable seal ring disposed between said primary and secondary body portions, a junk ring intermediate said seal ring and one of said body portions, and a pressure-responsive piston associated with said junk ring and extending freely through a passage in said seal ring, the arrangement being such that force exerted on said piston and said junk rings is transferred to said seal ring in an amount per unit area higher than the force per unit area exerted on said piston and said junk ring.

2. A well tool for packing-off an annular-section space between a well head and an inner concentric pipe string, comprising an annular primary body portion, an annular secondary body portion coaxial with and spaced from said primary body portion, a first resiliently deformable seal ring intermediate said primary and secondary body portions, a second resiliently deformable seal ring intermediate said first seal ring and said secondary body portion, a pair of junk rings intermediate said seal rings, and a plurality of pistons each of which is associated with a said junk ring and extends freely through a respective passage in a said seal ring, said pistons, said junk rings, and said seal rings being so interassociated that when said pistons and junk rings are pressed toward said seal rings, said seal rings are subjected to a force higher per unit area than that exerted on said pistons and said junk rings.

3. A well tool according to claim 2 wherein each of said junk rings has a plurality of pistons associated therewith.

4. A well tool according to claim 3 wherein the pistons associated with one junk ring are axially opposed to the pistons associated with the other junk ring.

5. A well tool according to claim 4 wherein said pistons are evenly spaced circumferentially about said junk rings.

6. A well tool according to any one of claims 2 to 5 wherein said pistons project through passages in said junk rings, and are retained therein by annular cap-like flanges.

7. A well tool for packing-off an annular-section space between a well head and a well string, comprising an annular rigid support element having inner and outer radially spaced surfaces, said support element having at least one axial bore intermediate its inner and outer radially spaced surfaces, a resiliently deformable seal ring having inner and outer radially spaced surfaces, and at least one axial bore intermediate its said inner and outer radially spaced surfaces, an axial end surface of the seal ring facing one axial end surface of the support element, and a piston extending into the respective bores in the support element and the seal ring and retained therein, the arrangement being such that, when the tool is in position in the said annular-section space and a pressure at the first force per unit area is exerted axially against the other axial end surface of the support element and an axial end surface of the piston, the said one axial end surface of the support element transmits said pressure to the end surface of the seal ring at a second force per unit are greater than said first force per unit area.

8. A well tool according to claim 7 wherein the support element and the seal ring have a like plurality of coaxial bores, and a like plurality of pistons extend into said bores.

9. A well tool according to claim 7 or claim 8 including means for holding the support element and the seal ring together.

10. A well tool according to any one of claims 7 to 9 wherein the piston is retained within the bores of the support element and of the seal ring by a radial flange-like head of greater cross-sectional area than that of the bore in the support element.

11. A well tool according to claim 10 wherein the bore in the support element is counterbored to receive the piston head.

12. A well tool according to any one of claims 7 to 11 wherein the magnitude X of the area of the said other axial end surface of the support element plus the area of the radial end surface of the piston is greater than the magnitude Y of the area of the end surface of the seal ring.

13. A well tool according to claim 12 wherein the ratio of magnitude X to magnitude Y is at least 1.05 to 1.

14. A well tool according to claim 13 wherein the ratio is 1.095 to 1.

15. A method of packing an annular-section space between a wall casing head and a tubular well string surrounded thereby, comprising the steps of installing a resiliently deformable seal ring and a rigid annular support element in

Since the piston can move freely in an axial direction with respect to the seal rings, when pressure is applied against the junk rings and the pistons in an axial direction tending to compress the seal rings between the junk rings and the body portions, this pressure is opposed by a seal ring surface of less area than the surface against which the pressure is applied, and the seal rings exert a proportionately greater pressure against the casing head and the casing. Hence, when the applied pressure is that of the well itself, the seal rings establish a fluid-tight barrier regardless of the pressure magnitude.

Furthermore, once the seal is established, any increase in well pressure will act through the junk-piston-seal ring combination to proportionately increase the sealing pressure, thereby assuring that the seal between the casing head and the casing remains intact.

WHAT WE CLAIM IS:—

1. A well tool, comprising an annular primary body portion, an annular secondary body portion axially spaced from said primary body portion, a resiliently deformable seal ring disposed between said primary and secondary body portions, a junk ring intermediate said seal ring and one of said body portions, and a pressure-responsive piston associated with said junk ring and extending freely through a passage in said seal ring, the arrangement being such that force exerted on said piston and said junk rings is transferred to said seal ring in an amount per unit area higher than the force per unit area exerted on said piston and said junk ring.

2. A well tool for packing-off an annular-section space between a well head and an inner concentric pipe string, comprising an annular primary body portion, an annular secondary body portion coaxial with and spaced from said primary body portion, a first resiliently deformable seal ring intermediate said primary and secondary body portions, a second resiliently deformable seal ring intermediate said first seal ring and said secondary body portion, a pair of junk rings intermediate said seal rings, and a plurality of pistons each of which is associated with a said junk ring and extends freely through a respective passage in a said seal ring, said pistons, said junk rings, and said seal rings being so interassociated that when said pistons and junk rings are pressed toward said seal rings, said seal rings are subjected to a force higher per unit area than that exerted on said pistons and said junk rings.

3. A well tool according to claim 2 wherein each of said junk rings has a plurality of pistons associated therewith.

4. A well tool according to claim 3 wherein the pistons associated with one junk ring are axially opposed to the pistons associated with the other junk ring.

5. A well tool according to claim 4 wherein said pistons are evenly spaced circumferentially about said junk rings.

6. A well tool according to any one of claims 2 to 5 wherein said pistons project through passages in said junk rings, and are retained therein by annular cap-like flanges.

7. A well tool for packing-off an annular-section space between a well head and a well string, comprising an annular rigid support element having inner and outer radially spaced surfaces, said support element having at least one axial bore intermediate its inner and outer radially spaced surfaces, a resiliently deformable seal ring having inner and outer radially spaced surfaces, and at least one axial bore intermediate its said inner and outer radially spaced surfaces, an axial end surface of the seal ring facing one axial end surface of the support element, and a piston extending into the respective bores in the support element and the seal ring and retained therein, the arrangement being such that, when the tool is in position in the said annular-section space and a pressure at the first force per unit area is exerted axially against the other axial end surface of the support element and an axial end surface of the piston, the said one axial end surface of the support element transmits said pressure to the end surface of the seal ring at a second force per unit are greater than said first force per unit area.

8. A well tool according to claim 7 wherein the support element and the seal ring have a like plurality of coaxial bores, and a like plurality of pistons extend into said bores.

9. A well tool according to claim 7 or claim 8 including means for holding the support element and the seal ring together.

10. A well tool according to any one of claims 7 to 9 wherein the piston is retained within the bores of the support element and of the seal ring by a radial flange-like head of greater cross-sectional area than that of the bore in the support element.

11. A well tool according to claim 10 wherein the bore in the support element is counterbored to receive the piston head.

12. A well tool according to any one of claims 7 to 11 wherein the magnitude X of the area of the said other axial end surface of the support element plus the area of the radial end surface of the piston is greater than the magnitude Y of the area of the end surface of the seal ring.

13. A well tool according to claim 12 wherein the ratio of magnitude X to magnitude Y is at least 1.05 to 1.

14. A well tool according to claim 13 wherein the ratio is 1.095 to 1.

15. A method of packing an annular-section space between a wall casing head and a tubular well string surrounded thereby, comprising the steps of installing a resiliently deformable seal ring and a rigid annular support element in

the annular-section space circumscribing the well string, a pressure-responsive piston associated with the support element extending freely through a passage in the seal ring, axially compressing the seal ring so that it establishes a primary fluid-tight seal between the well string and casing head, applying an axial force against the support element and the piston to bias the support element against the seal ring, and transmitting the force to the seal ring at a force per unit area greater than the force per unit area applied against the support element and piston.

16. A method according to claim 15 wherein the axial force applied against the support element is provided by fluid pressure in the annular-section space.

17. A well tool substantially as hereinbefore described with reference to the accompanying drawings.

MATHISEN & MACARA,
Chartered Patent Agents,
Lyon House, Lyon Road,
Harrow, Middlesex.
Agents for the Applicants.

Printed for Her Majesty's Stationery Office by the Courier Press, Leamington Spa, 1972.
Published by the Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.

