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J. C. ST. JOHN ET AL

3,266,571

CASING SLOTTING

Filed March 5, 1964

FIG. 1

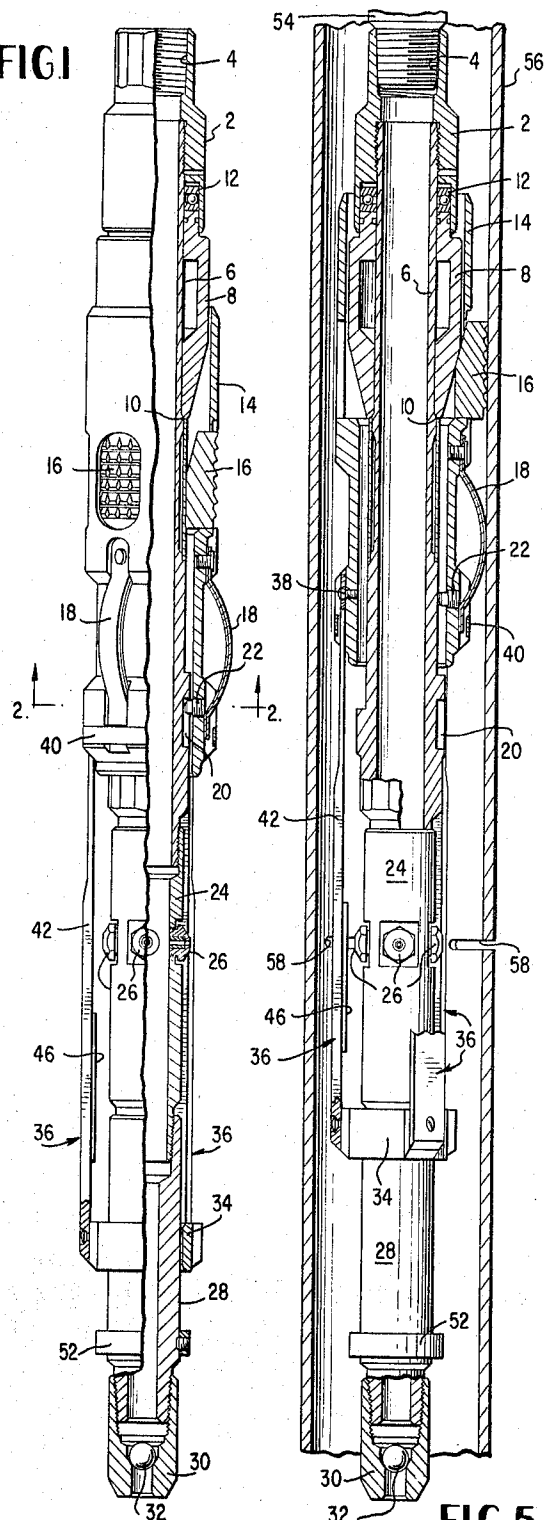


FIG. 3

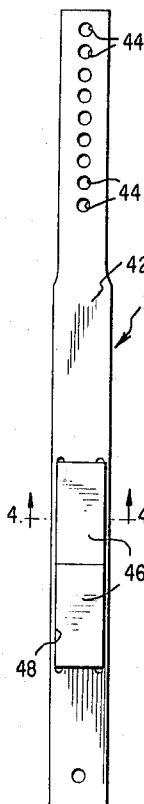


FIG. 4

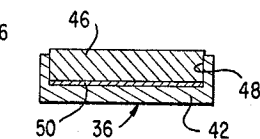


FIG. 1A

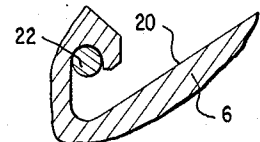


FIG. 2

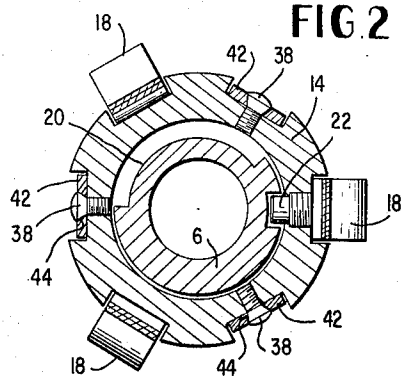


FIG. 5

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CASING SLOTTING

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This invention relates to perforating a well casing, and more particularly, to the method and apparatus for forming discontinuous slots in a well casing.

For fracture initiation, it is often desirable to cut horizontal slots in a well casing. One tool which is suitable for forming the horizontal slots is a fluid jet tool which perforates the casing. The fluid jet tool has radial nozzles for directing a stream of abrasive laden fluid outwardly against the casing. When the tool is positioned at the desired depth, the abrasive laden fluid is pumped down the tubing and through the radial nozzles at a high velocity to perforate the casing opposite the nozzles.

If horizontal slots are to be cut in the casing, it is necessary to rotate the tubing string, so that the nozzles of the fluid jet tool move in a horizontal plane. Unless the length of the slots can be controlled, however, the casing will be severed in the plane of the nozzles, and if it is unsupported, the upper portion of the casing may be displaced downwardly by its own weight.

Accordingly, it is an object of this invention to provide a method and apparatus for forming horizontal discontinuous slots in a casing.

It is a further object of this invention to provide an efficient method and apparatus for controlling the length and number of horizontal slots which are formed in a casing after it has been set in a well.

It is a still further object of this invention to provide a fluid jet slotting tool which is re-usable.

These objects are accomplished in accordance with a preferred embodiment of the invention by a hydraulic perforating tool which is attached to a tubing string. The perforating tool is supported for rotation in the casing and has a plurality of radial jet nozzles for directing abrasive laden fluid under pressure against the wall of the casing. The nozzle portion of the tool is mounted in a sleeve having slips which expand outwardly against the casing to hold the sleeve stationary while the nozzle portion of the tool may be rotated by the tubing string. A plurality of elongated shields are spaced circumferentially around the nozzle portion and are secured at one end to the sleeve. The opposite end of each shield is fastened to a stationary ring on the side of the nozzles opposite the sleeve. Since the shields extend along the interior of the casing, they form a barrier to protect a portion of the casing from the fluid stream issuing from the nozzles, as the nozzle portion of the tool rotates. Accordingly, that portion of the casing which is protected by the shields is not perforated by the jet stream, while the exposed portion of the casing is perforated by the stream issuing from the nozzles. As the nozzle portion rotates, therefore, a discontinuous slot is formed in the casing.

This preferred embodiment of the invention is illustrated in the accompanying drawings in which:

FIG. 1 is an elevational view, partially in section, showing the hydraulic perforating tool of this invention;

FIG. 1A is a schematic view of the J-slot on a tubing anchor mandrel;

FIG. 2 is a cross sectional view along the line 2—2 in FIG. 1;

FIG. 3 is an enlarged detail view of a shield;

FIG. 4 is a cross sectional view of the shield along the line 4—4 in FIG. 3; and

FIG. 5 is a cross sectional view, partially in section,

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showing the tool of this invention set in a well casing.

As shown in FIG. 1, the perforating tool of this invention includes a bearing housing 2 having internal threads 4 at its upper end for being coupled to the end of a tubing string. A mandrel 6 is threadedly secured to the interior of the bearing housing 2 and extends downwardly from the housing. A wedge body 8 is mounted in telescoping relation over the mandrel 6 and a shoulder 10 on the mandrel 6 resists downward axial movement of the wedge body 8 relative to the mandrel 6. A bearing assembly 12 is mounted within a cylindrical recess in the bearing housing 2. The bearing assembly 12 facilitates rotation of the mandrel 6 and the housing 2 relative to the wedge body 8. A slip retaining sleeve 14 is also mounted in telescoping relation over the mandrel 6. A plurality of slips 16 on the sleeve 14 are movable radially outwardly from the sleeve to engage a casing, but are urged radially inwardly by conventional spring means, not shown. The slip retaining sleeve 14 also has a plurality of drag springs 18 extending outwardly from the sleeve for engaging the casing. A J-slot 20 in the mandrel 6, as shown schematically in FIG. 1A, cooperates with a lug 22 in the sleeve 14 for controlling relative movement between the sleeve 14 and the mandrel 6.

A nozzle body 24 is threadedly secured to the lower end of the mandrel 6 and a plurality of nozzles 26 extend radially outwardly through the body 24. Each of the nozzles 26 is threadedly secured in a hole in the body 24 and although there are four nozzles in the body 24 shown in FIG. 1, some of the nozzles may be replaced by plugs, or additional holes may be provided for a greater number of nozzles in the body 24. A mandrel 28 is threadedly secured to the lower end of the nozzle body 24 and a valve body 30 is secured to the lower end of the mandrel 28. A ball 32 in the valve body 30 prevents fluid in the mandrel 28 from flowing out through the bottom of the valve body 30, but allows fluid to flow upwardly into the mandrel 28. A ring 34 extends around the mandrel 28 and is movable relative thereto. A plurality of elongated shields 36 are secured at one end to the ring 34 and at the opposite end to the sleeve 14 by a screw 38. The shields 36 extend through an opening between the sleeve 14 and a slip retaining strap 40 which is welded or otherwise secured on the sleeve 14.

As shown in FIGS. 3 and 4, each of the shields includes a strip 42, which is preferably formed of metal. The strip has a plurality of holes 44 which are spaced along one end of the shield. Each of the holes 44 is adapted to receive a screw corresponding to the screw 38. Abrasive resistant blocks 46 are secured in a rectangular recess 48 in one side of the strip 42. By selecting one of the holes 44, the axial distance between the blocks 46 and the nozzles 26 may be adjusted. The blocks 46 are preferably formed of an extremely hard material, such as a tungsten carbide, and the strips 42 are preferably formed of spring steel. Since the difference between the coefficient of thermal expansion of the steel strip 42 and that of the tungsten carbide block 46 is great, the blocks 46 will crack, if they are heated sufficiently to bond the block to the strip by welding or soldering. Therefore, it is necessary to provide a sheet 50 having a high heat conductivity between the carbide blocks 46 and the mild steel strip 42. One metal alloy which has a high conductivity and is suitable for the sheet 50 is constantan alloy. Each of the shields 36 having its abrasion resistant blocks 46 facing toward the nozzle body 24, as shown in FIG. 1, is secured at its opposite ends to the sleeve 14 and the ring 34. The ring 34 is free to slide along the mandrel 28 when the sleeve 14 is displaced axially relative to the man-

drel 6 and a junk catcher 52 is secured to the mandrel 28 to limit the downward movement of the ring 34.

As shown in FIG. 5, when the bearing housing 2 is threadedly secured to the lower end of a tubing string 54, and run in a casing 56, the tool must be anchored to the casing 54 before the perforation operation begins. As the tool is lowered in the well, the drag springs 18 engage the wall of the casing 56, but the lug 22 is lodged in the hooked portion of the J-slot 20, as shown in FIG. 1A, and the sleeve 14 cannot move relative to the mandrel 6. Therefore, the slips 16 remain retracted. When the desired depth is reached, the tubing string is raised slightly and given a right hand rotation to move the lug out of the hooked portion of the J-slot. Since the lug is then in the open portion of the J-slot, the mandrel 6 may move downwardly relative to the sleeve 14, until the slips 16 are cammed radially outward against the casing 56 by the wedge body 8 to hold the sleeve stationary while the mandrel 6 is rotating. Since the shields 36 are fastened at one end to the sleeve 14, they are also held stationary by the sleeve and do not rotate. As the mandrel 6 is moved downwardly relative to the sleeve 14, the nozzles 26 move axially relative to the shields 36 until they are positioned opposite the blocks 46 as shown in FIG. 5.

The tool may be retrieved by raising the tubing 54 to move the mandrel 6 upwardly relative to the sleeve 14 and by left hand rotation of the tubing 54 to move the lug 22 into the hooked portion of the J-slot 20. The slips 16 are retracted by their springs and the tool is then free of the casing 56 and may be moved to another location or taken out of the well.

In operation, the sleeve 12 and wedge body 8 are anchored to the casing 56 by the slips 16, as previously described. The tubing 54 is then rotated slowly and an abrasive laden fluid is pumped down the tubing string 54 and through the mandrel 6. The ball 32 in the valve body 30 prevents the fluid from flowing out through the bottom of the tool and the fluid pressure forces the fluid through the nozzles 26 and against the casing 56 with sufficient velocity to erode the metal casing 56 and form a slot 58 in the casing. The shields 36 protect a portion of the casing 56 from the stream of fluid issuing from the nozzles 26, so that as the nozzle body 24 rotates, the fluid stream forms a slot in the casing 56, but the slot is interrupted at the location of the shields 36. The width of the shields 36 and the number of the shields may be varied, as desired, to produce various proportions of discontinuous slots in the casing 56. After the discontinuous slot has been formed, the position of the shields relative to the nozzles may be adjusted and additional slots may be cut.

As an example of the operation of the tool of this invention, two $\frac{3}{16}$ " jet nozzles were mounted 180° apart in the nozzle body 24, which was run in several joints of casing. The abrasive laden fluid was a gelled mud carrying one pound of 20-40 Ottawa sand per gallon. The fluid was pumped down the tubing at 2500 p.s.i. while the nozzle body 24 was rotating at 24 revolutions per minute. In eleven minutes the casing was perforated and in eight more minutes the slots were completed in the casing. The tungsten carbide blocks were broken out in the path of the jet stream, but the shields were not cut apart and could be re-used by adjusting the position of the blocks longitudinally relative to the nozzles.

This invention provides a rapid and practical method and apparatus for forming discontinuous slots in a casing. The shields 36 have a relatively long life, although they are subjected to the abrasive jet stream, since the position of the strips is adjustable relative to the nozzles. If the shields become worn, they may easily be replaced.

While this invention has been illustrated and described in one embodiment, it is recognized that variations and changes may be made therein without departing from the invention as set forth in the claims.

We claim:

1. A tool for perforating well casing comprising means for directing an abrasive fluid stream against the casing, and means for shielding a predetermined portion of the casing from the fluid stream, said directing means being adapted for rotation relative to said shielding means whereby the stream forms a discontinuous slot in the casing as the directing means rotates relative to the shielding means.

2. A tool for perforating well casing comprising conduit means, means for coupling the conduit means to a tubing string, a sleeve on the conduit means, means for securing the sleeve to the casing, said conduit means being movable relative to the sleeve, means on the conduit means for directing an abrasive fluid stream against the casing, and means on the sleeve for shielding a predetermined portion of the casing from the fluid stream, whereby the stream forms a discontinuous slot in the casing.

3. A tool for perforating well casing comprising conduit means, means for coupling the conduit means to a tubing string, a sleeve on the conduit means, means for securing the sleeve to the casing, said conduit means being movable relative to the sleeve, means on the conduit means for directing an abrasive fluid stream against the casing, a shield extending between the directing means and the casing, and means for securing the shield to the sleeve, whereby a portion of the casing is shielded from the fluid stream to form discontinuous slots.

4. A tool for perforating well casing comprising conduit means, means for coupling the conduit means to a tubing string, a sleeve on the conduit means, means for securing the sleeve to the casing, said conduit means being movable relative to the sleeve, means on the conduit means for directing an abrasive fluid stream against the casing, a strip extending between the directing means and the casing, a ring mounted on the conduit means, and means for securing one end of the strip to the ring and the opposite end to the sleeve, whereby the strip shields a portion of the casing from the fluid stream.

5. A tool for perforating well casing comprising conduit means, means for coupling the conduit means to a tubing string, a sleeve on the conduit means, means for securing the sleeve to the casing, said conduit means being movable relative to the sleeve, means on the conduit means for directing an abrasive fluid stream against the casing, a strip extending between the directing means and the casing, said strip having an abrasive resistant segment secured thereto on the side of the strip adjacent the directing means, a ring mounted on the conduit means, and means for securing one end of the strip to the ring and the opposite end to the sleeve, whereby the strip shields a portion of the casing from the fluid stream.

6. A tool for perforating well casing comprising conduit means, means for coupling the conduit means to a tubing string, a sleeve on the conduit means, means for securing the sleeve to the casing, said conduit means being movable relative to the sleeve, means on the conduit means for directing an abrasive fluid stream against the casing, a strip extending between the directing means and the casing, said strip having an abrasion resistant segment secured thereto on the side of the strip adjacent the directing means, an intermediate material interposed between said abrasion resistant material and said strip, said intermediate material having a coefficient of thermal expansion between that of said resistant segment and said strip, a ring mounted on the conduit means, and means for securing one end of the strip to the ring and the opposite end to the sleeve, whereby the strip shields a portion of the casing from the fluid stream.

7. A perforating tool as defined in claim 6, wherein said abrasion resistant segment is tungsten carbide, said bonding material is constantan and said strip is formed of steel.

8. A tool for perforating well casing comprising conduit means, means for coupling the conduit means to a

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tubing string, a sleeve on the conduit means, means for securing the sleeve to the casing, said conduit means being movable relative to the sleeve, means on the conduit means for directing an abrasive fluid stream against the casing, a strip extending between the directing means and the casing, a ring mounted on the conduit means, means for securing one end of the strip to the ring and the opposite end to the sleeve, and means for adjusting the position of the strip longitudinally relative to said directing means, whereby different portions of the strip may be exposed to the fluid stream.

9. A tool for perforating well casing comprising conduit means, means for coupling the conduit means to a tubing string, a sleeve on the conduit means, said sleeve having slips mounted therein, means for selectively expanding the slips against the casing, means forming a bearing for rotation of the conduit means relative to the sleeve, means on the conduit means for directing an abrasive fluid stream against the casing, and means on the sleeve for shielding a predetermined portion of the casing from the fluid stream, whereby the stream forms a discontinuous slot in the casing.

10. A tool for perforating well casing comprising conduit means, means for coupling the conduit means to a tubing string, a sleeve on the conduit means, means for securing the sleeve to the casing, said conduit means being movable relative to the sleeve and having radial nozzles therein, a shield extending between the nozzles and the casing, and means for securing the shield to the sleeve, whereby a portion of the casing is protected from the fluid stream to form discontinuous slots.

11. A method for forming radial slots in a casing comprising directing a stream of abrasive fluid against said

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casing, rotating the directing means relative to the casing, and shielding a portion of the casing from the fluid stream.

12. A method for forming radial slots in a casing comprising positioning a shield in a casing, directing a stream of abrasive fluid against said casing adjacent the shield, and rotating the directing means relative to the shield and the casing, whereby a discontinuous radial slot is formed in the casing.

13. A method for forming a plurality of radial slots in a casing comprising positioning a shield in a casing, directing a stream of abrasive fluid against said casing adjacent the shield, rotating the directing means relative to the shield and the casing, changing the position of the directing means relative to the casing, changing the position of the shield relative to the directing means, directing a stream of abrasive fluid against said casing adjacent the shield, and rotating the directing means relative to the shield and the casing, whereby a different portion of the shield is exposed to the abrasive fluid stream.

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