

**FRACTURING AND GRAVEL PACKING TOOL WITH
SHIFTING ABILITY BETWEEN SQUEEZE AND
CIRCULATE WHILE SUPPORTING AN INNER STRING
ASSEMBLY IN A SINGLE POSITION**

Inventors: Nicholas J. Clem; Martin P. Coronado; Jeffery D. Kitzman
and Jeffry S. Edwards

FIELD OF THE INVENTION

[0001] The field of this invention relates to gravel packing and fracturing tools used to treat formations and to deposit gravel outside of screens for improved production flow through the screens.

BACKGROUND OF THE INVENTION

[0002] Completions whether in open or cased hole can involve isolation of the producing zone or zones and installing an assembly of screens suspended by an isolation packer. An inner string typically has a crossover tool that is shifted with respect to the packer to allow fracturing fluid pumped down the tubing string to get into the formation with no return path to the surface so that the treating fluid can go into the formation and fracture it or otherwise treat it. The crossover tool also can be configured to allow gravel slurry to be pumped down the tubing to exit laterally below the set packer and pack the annular space outside the screens. The carrier fluid can go through the screens and into a wash pipe that is in fluid communication with the crossover tool so that the returning fluid crosses over through the packer into the upper annulus above the set packer.

[0003] Typically these assemblies have a flapper valve in the wash pipe to prevent fluid loss into the formation during certain operations such as reversing out excess gravel from the tubing string after the gravel packing operation is completed. Some schematic representations of known gravel packing systems are shown schematically in USP 7,128,151 and in more functional detail in USP 6,702,020. Other features of gravel packing systems are found in USP 6,230,801. Other patents and applications focus on the design of the crossover housing where there are erosion issues from moving slurry through ports or against housing walls on the way out such as shown in US Applications 11/586,235 filed October 25, 2006 and application 12/250,065 filed October 13, 2008. Locator tools that use displacement of

fluid as a time delay to reduce applied force to a bottom hole assembly before release to minimize a slingshot effect upon release are disclosed in US Publication 2006/0225878. Also relevant to time delays for ejecting balls off seats to reduce formation shock is USP 6,079,496. Crossover tools that allow a positive pressure to be put on the formation above hydrostatic are shown in US Publication 2002/0195253. Other gravel packing assemblies are found in USP 5,865,251; 6,053,246 and 5,609,204.

[0004] These known systems have design features that are addressed by the present invention. One issue is well swabbing when picking up the inner string. Swabbing is the condition of reducing formation pressure when lifting a tool assembly where other fluid can't get into the space opened up when the string is picked up. As a result the formation experiences a drop in pressure. In the designs that used a flapper valve in the inner string wash pipe this happened all the time or some of the time depending on the design. If the flapper was not retained open with a sleeve then any movement uphole with the inner string while still sealed in the packer bore would swab the well. In designs that had retaining sleeves for the flapper held in position by a shear pin, many systems had the setting of that shear pin at a low enough value to be sure that the sleeve moved when it was needed to move that it was often inadvertently sheared to release the flapper. From that point on a pickup on the inner string would make the well swab. Some of the pickup distances were several feet so that the extent of the swabbing was significant.

[0005] The present invention provides an ability to shift between squeeze and circulation modes using the packer as a frame of reference where the movements between those positions do not engage the wash pipe valve for operation. In essence the wash pipe valve is held open and it takes a pattern of deliberate steps to get it to close. In essence a pickup force against a stop has to be applied for a finite time to displace fluid from a variable volume cavity through an orifice. It is only after holding a predetermined force for a predetermined time that the wash pipe valve assembly is armed by allowing collets to exit a bore. A pattern of passing through the bore in an opposed direction and then picking up to get the collets against the bore they just passed through in the opposite direction that gets the valve to close. Generally

this is done after gravel packing when pulling the assembly out to prevent fluid losses into the formation.

[0006] The extension ports can be closed with a sleeve that is initially locked open but is unlocked by shifting tool on the wash pipe as it is being pulled up. The sleeve is then shifted over the ports in the outer extension and locked into position. This restricts subsequent production to enter the production string only through the screens. For run in this same sleeve is used to prevent flow out the crossover ports so that a dropped ball can be pressurized to set the packer initially.

[0007] The upper valve assembly that indexes off the packer has the capability of allowing reconfiguration after normal operations between squeezing and circulation while holding the wash pipe valve open. The upper valve assembly also has the capability to isolate the formation against fluid loss in the squeeze or circulate positions when supported off the packer or in the reverse position when supported off the smart collet. An optional ball seat can be provided in the upper valve assembly so that acid can be delivered through the wash pipe and around the initial ball dropped to set the packer so that as the wash pipe is being lifted out of the well acid can be pumped into the formation adjacent the screen sections as the lower end of the wash pipe moves past them.

[0008] These and other advantages of the present invention will be more apparent to those skilled in the art from a review of the detailed description of the preferred embodiment and the associated drawings that appear below with the understanding that the appended claims define the literal and equivalent scope of the invention.

SUMMARY OF THE INVENTION

[0009] A fracturing and gravel packing tool has features that prevent well swabbing when the tool is picked up with respect to a set isolation packer. An upper or jet valve allows switching between the squeeze and circulation positions without risk of closing the wash pipe valve. The wash pipe valve can only be closed with multiple movements in opposed direction that occur after a predetermined force is held for a finite time to allow movement that arms the wash pipe valve. The jet valve can prevent fluid loss

to the formation when being set down whether the crossover tool is supported on the packer or on the smart collet. A lockable sleeve initially blocks the gravel exit ports to allow the packer to be set with a dropped ball. The gravel exit ports are pulled out of the sleeve for later gravel packing. That sleeve is unlocked after gravel packing with a shifting tool on the wash pipe to close the gravel slurry exit ports and lock the sleeve in that position for production through the screens. The jet valve can be optionally configured for a second ball seat that can shift a sleeve to allow acid to be pumped through the wash pipe lower end and around the initial ball that was landed to set the packer. That series of movements also blocks off the return path so that the acid has to go to the wash pipe bottom.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] FIG. 1 is a system schematic representation to show the major components in the run in position;

[0011] FIG. 2 is the view of FIG. 1 in the packer set position;

[0012] FIG. 3 is the view of FIG. 2 in the squeeze position;

[0013] FIG. 4 is the view of FIG. 3 in the circulate position;

[0014] FIG. 5 is the view of FIG. 4 in the metering position which is also the reverse out position;

[0015] FIG. 6 shows how to arm the wash pipe valve so that a subsequent predetermined movement of the inner string can close the wash pipe valve;

[0016] FIG. 7 is similar to FIG. 5 but the wash pipe valve has been closed and the inner assembly is in position for pulling out of the hole for a production string and the screens below that are not shown;

[0017] FIGS. 8a-j show the run in position of the assembly also shown in FIG. 1;

[0018] FIGS. 9a-b the optional additional ball seat in the jet valve before and after dropping the ball to shift a ball seat to allow acidizing after gravel packing on the way out of the hole;

[0019] FIGS. 10a-c are isometric views of the ball valve assembly that is located near the lower end of the inner string;

[0020] FIGS. 11a-j show the tool in the squeeze position of FIG. 3;

[0021] FIGS. 12a-j show the tool in the circulate position where gravel can be deposited, for example;

[0022] FIGS. 13a-j show the metering position which can arm the wash pipe valve to then close; and

[0023] FIGS. 14a-j show the apparatus in the reverse position with the wash pipe valve open.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0024] Referring to FIG. 1, a wellbore **10** that can be cased or open hole has in it a work string **12** that delivers an outer assembly **14** and an inner assembly **16**. At the top of the outer assembly is the isolation packer **18** which is unset for run in FIG. 1. A plurality of fixed ports **20** allow gravel to exit into the annulus **22** as shown in FIG. 4 in the circulation position. A tubular string **24** continues to a series of screens that are not shown at the lower ends of FIG. 1-7 but are of a type well known in the art. There may also be another packer below the screens to isolate the lower end of the zone to be produced or the zone in question may go to the hole bottom.

[0025] The inner string **16** has a multi-passage or jet valve or ported valve assembly **26** that is located below the packer **18** for run in. Seals **28** are below the jet valve **26** to selectively seal into the packer bore for the squeeze position shown in FIG. 3. Seals **28** are also below the packer bore during run in to maintain hydrostatic pressure on the formation prior to, and after setting, the packer.

[0026] Gravel exit ports **30** are held closed for run in against sleeve **32** and seals **34** and **36**. Metering collets **38** are shown initially in bore **40** while the smart collet **42** and the wash pipe valve assembly **44** are supported below bore **40**. Alternatively, the entire assembly of collets **38**, smart collet **42** and wash pipe assembly **44** can be out of bore **40** for run in. Valve assembly **44** is locked open for run in. A ball seat **46** receives a ball **48**, as shown in FIG. 2 for setting the packer **18**.

[0027] When the packer **18** has been positioned in the proper location and is ready to be set, the ball **48** is pumped to seat **46** with ports **30** in the closed position, as previously described. The applied pressure sets a known packer setting tool and the packer **18** is now set in the FIG. 2 position. Arrows

48 represent the pressure being applied to the known packer setting tool (not shown) to get the packer **18** set.

[0028] In FIG. 3 the string **12** is raised and the collets **50** land on the packer **18**. With weight set down on the string **12** seals **52** and **54** on the jet valve **26** isolates the upper annulus **56** from the annulus **22**. Flow down the string **12** represented by arrows **58** enters ports **30** and then ports **20** to get to the annulus **22** so that gravel slurry represented by arrows **58** can fill the annulus **22** around the screens (not shown). The jet valve **26** has a j-slot mechanism which will be described below that allows the string **12** to be picked up and set down to get seal **52** past a port so as to open a return flow path that is shown in FIG. 4. It should be noted that picking up the string **12** allows access to the annulus **22** every time to avoid swabbing the formation by connecting it fluidly to the upper annulus **56**. On the other hand, setting down on string **12** while the collets **50** rest on the packer **18** will close off the return path to the upper annulus **56** by virtue of seal **52** going back to the FIG. 3 position. This is accomplished with a j-slot mechanism that will be described below. In the circulation mode of FIG. 4 the return flow through the screens (not shown) is shown by arrows **60**. The positions in FIGS. 3 and 4 can be sequentially obtained with a pickup and set down force using the j-slot assembly mentioned before.

[0029] In FIG. 5 the string **12** has been raised until the metering dogs **38** have landed on a shoulder **62**. A pull of a predetermined force for a predetermined time will displace fluid through an orifice and ultimately allow the dogs **38** to collapse into or past bore **64** as shown in FIG. 6. Also, picking up to the FIG. 5 position lets the smart collet **42** come out of bore **40** so that it can land on shoulder **66** for selective support. Picking up the smart collet **42** off shoulder **66** and then setting it down again will allow the smart collet **42** to re-enter bore **40**.

[0030] Once the valve assembly **44** is pulled past bore **40** as shown in FIG. 6 it is armed. This means that pushing valve assembly back through bore **40** followed by picking up to pull valve assembly **44** back into bore **40** will close the valve assembly **44**. The valve assembly can re-enter bore **40** to go to the FIG. 7 position for coming out of the hole. It should be noted that

reversing out can be done in the FIG. 5 or FIG. 7 positions with valve **44** open or closed. On the other hand, valve **44** having been closed can be reopened by landing it on shoulder **66** after lifting past it and then setting down weight.

[0031] FIGS. 8a-8j represent the tool in the run in position. The major components will be described in an order from top to bottom to better explain how they operate. Thereafter, additional details and optional features will be described followed by the sequential operation that builds on the discussion provided with FIGS. 1- 7. The work string **12** is shown in FIG. 8a as is the top of the packer setting tool **70** that is a known design. It creates relative movement by retaining the packer upper sub **72** and pushing down the packer setting sleeve **74** with its own sleeve **76**. The packer upper sub **72** is held by the setting tool **70** using sleeve **78** that has flexible collets at its lower end supported for the setting by sleeve **80**. After a high enough pressure to set the packer **18** has been applied in passage **86** and into ports **84**, sleeve **80** is pushed up to undermine the fingers at the lower end of sleeve **78** so that the packer upper sub **72** is released by the setting tool **70**. The initial buildup of pressure in passage **82** communicates through ports **86** in FIG. 1a to move the setting sleeve **76** of the setting tool **70** down against the packer setting sleeve **74** to set the packer **18** by pushing out the seal **88** and slip assembly **87**. It is worth noting that in the preferred embodiment the packer setting tool sets the packer at 4000 PSI through port **86**. The pressure is then released and a pull is delivered to the packer with the work string to make sure the slips have set properly. At that point pressure is applied again. Sleeve **80** will move when 5000 PSI is applied.

[0032] Continuing down on the outside of the packer **18** to FIG. 8d there are gravel slurry outlets **20** also shown in FIG. 1 which are a series of holes in axial rows that can be the same size or progressively larger in a downhole direction and they can be slant cut to be oriented in a downhole direction. These openings **20** have a clear shot into the lower annulus **22** shown in FIG. 1. Continuing at FIG. 8d and below the string **24** continues to the screens that are not shown.

[0033] Referring now to FIGS. 8b-d the jet tool **26** will now be described. The top of the tool **26** is at **90** and rests on the packer upper sub **72**

for run in. Spring loaded collets **50** shown extended in the squeeze position of FIG. 3, are held against the packer upper sub **72** by a spring **92**. Upper mandrel **94** extends down from upper end **90** to a two position j-slot assembly **96**. The j-slot assembly **96** operably connects the assembly of connected sleeves **98** and **100** to mandrel **94**. Sleeve **100** terminates at a lower end **102** in FIG. 8d. Supported by mandrel **94** is ported sleeve **104** that has ports **106** through which flow represented by arrows **60** in FIG. 4 will pass in the circulation mode when seal **52** is lifted above ports **106**. Below ports **106** is an external seal **108** that in the run in position is below the lower end **110** of the packer upper sub **72** and seen in FIG. 8c. Note also that sleeve **100** moves within sleeve **112** that has ports **30** covered for run in by sleeve **114** and locked by dog **116** in FIG. 8e. Ports **30** need to be covered so that after a ball is dropped onto seat **118** the passage **82** can be pressured up to set the packer **18**.

[0034] A flapper valve **120** is held open by sleeve **122** that is pinned at **124**. When the ball (first shown in corresponding FIG. 9) is landed on seat **118** and pressure in passage **82** is built up, the flapper is allowed to spring closed against seat **126** so that downhole pressure surges that might blow the ball (not shown in this view) off of seat **118** will be stopped.

[0035] Going back to FIGS. 8a-b, when pressure builds on passage **82** it will go through ports **128** and lift sleeve **130**. The lower end of sleeve **130** serves as a rotational lock to the packer body or upper sub **72** during run in so that if the screens get stuck during run in they can be rotated to free them. After the proper placement for the packer **18** is obtained, the rotational lock of item **130** is no longer needed and it is forced up to release by pressure in passage **82** after the ball is dropped. Piston **134** is then pushed down to set the packer **18** and then piston **136** can move to prevent overstressing the packer seal and slip assembly **88** during the setting process. The setting tool **70** is now released from the packer upper sub **72** and the string **12** can be manipulated.

[0036] Coming back to FIGS. 8b-c, with the packer **18** set, the top **90** of the jet tool **26** can be raised up by pulling up on sleeves **98** and **100** to raise mandrel **94** after shoulders **95** and **97** engage, which puts groove **134** behind collets **50** while compressing spring **92**. Ultimately the collets **50** will spring

out at the location where top end **90** is located in FIG. 8b. With mandrel **94** and everything that hangs on it including sleeve **104**, supported off the packer upper sub **72** the assembly of connected sleeves **98** and **100** can be manipulated up and down and in conjunction with j-slot **96** can come to rest at two possible locations after a pickup and a set down force of a finite length. In one of the two positions of the j-slot **96** the seal **52** will be below the ports **106** as shown in FIG. 8c. In the other position of the j-slot **96** the seal **52** will move up above the ports **106**. In essence seal **52** is in the return flow path represented by arrows **60** in FIG. 4 in the circulate mode which happens when seal **52** is above ports **106** and the squeeze position where the return path to the upper annulus **56** is closed as in FIG. 3 and in the run in position of FIG. 8c.

[0037] It should be noted that every time the assembly of sleeves **98** and **100** is picked up the seal **52** will rise above ports **106** and the formation will be open to the upper annulus **56**. This is significant in that it prevents the formation from swabbing as the inner string **16** is picked up. If there are seals around the inner string **16** when it is raised for any function, the raising of the inner string **16** will reduce pressure in the formation or cause swabbing which is detrimental to the formation. As mentioned before moving up to operate the j-slot **96** or lifting the inner string to the reverse position of FIGS. 5 or 7 will not actuate the valve **44** nor will it swab the formation. The components of the jet valve have now been described; however there is an optional construction where the return path **136** shown above ports **106** in FIG. 8c is different. The purpose of this alternative embodiment is to allow pumping fluid down passage **82** as the inner string **16** is removed and to block paths of least resistance so that fluid pumped down passage **82** will go down to the lower end of the inner string **16** past the open valve **44** for the purpose of treating from within the screens with acid as the lower end of the inner string **16** moves up the formation on the way out of the wellbore.

[0038] First to gain additional perspective, it is worth noting that the return path **138** around the flapper **120** in FIG. 8e starts below the ports **30** and bypasses them as shown by the paths in hidden lines and then continues in the run in position until closed off at seal **52** just below the ports **106** in FIG.

8c. Referring now to FIG. 9a part **112'** has been redesigned and part **140** is added to span between parts **100** that is inside part **140** at the top and part **112'** that surrounds it at the bottom. Note that what is shown in FIGS. 9a-b is well above the ball seat **118** that was used to set the packer **18** and that is shown in FIG. 8e. Even with this optional design for the jet valve **26** it should be stated that the ball **142** is not dropped until after the gravel packing and reversing out steps are done and the inner string **16** is ready to be pulled out. Note that return path **138'** is still there but now it passes through part **112'** at ports **144** and **146** and channel **138'** on the exterior of part **140**. Ports **150** are held closed by seals **152** and **154**. Ports **156** are offset from ports **150** and are isolated by seals **154** and **158**. Ball **142** lands on seat **160** held by dog **162** to part **140**. When ball **142** lands on seat **160** and pressure builds to undermine dogs **162** so that part **140** can shift down to align ports **150** and **156** between seals **152** and **154** while isolating ports **144** from ports **146** with seal **164**. Now acid pumped down passage **82** cannot go uphole into return path **138'** because seal **164** blocks it. It is fine for the acid to go downhole into passage **138'** as by that time after the gravel packing the flow downhole into path **138'** will simply go to the bottom of the inner string **16** as it is pulled out of the whole, which is the intended purpose anyway which is to acidize as the inner string is pulled out of the hole.

[0039] Referring now to FIGS. 8e-g the inner string **16** continues with metering sub **166** that continues to the smart collet sub **168** in FIG. 8g. The metering assembly **38** is shown in FIGS. 1-7. It comprises a series of dogs **170** that have internal grooves **172** and **174** near opposed ends. Metering sub **166** has humps **176** and **178** initially offset for run in from grooves **172** and **174** but at the same spacing. Humps **176** and **178** define a series of grooves **180**, **182** and **184**. For run in the dogs **170** are radially retracted into grooves **180** and **182**. When the inner string **16** is picked up, the dogs **170** continue moving up without interference until hitting shoulder **186** in FIG. 8d. Before that point is reached, however, the dogs **170** go into a bigger bore than the run in position of FIG. 8f and that is when spring **188** pushes the dogs **170** down relative to the metering sub **166** to hold the dogs **170** in the radially extended position up on humps **176** and **178** before the travel stop shoulder **186** is

engaged by dogs **170**. In order for the metering sub to keep moving up after the dogs **170** shoulder out it has to bring with it smart collet sub **168** and that requires reducing the volume of chamber **190** which is oil filled by driving the oil through orifice **192** and passage **194** to chamber **196** to displace piston **198** against spring **200**. It takes time to do this and this serves as a surface signal that if the force is maintained on the inner string **16** that valve **44** will be armed as shown in FIG. 6. If the orifice **192** is plugged, a higher force can be applied than what it normally takes to displace the oil from chamber **190** and a spring loaded safety valve **202** will open to passage **204** as an alternate path to chamber **196**. When enough oil has been displaced, the inner string **16** moves enough to allow the opposed ends of the dogs **170** to pop into grooves **182** and **184** to undermine support for the dogs **170** while letting the inner string **16** advance up. The valve **44** is now armed but still in the open position. It will take lowering it and raising valve **44** to get it to close.

[0040] Pulling the metering sub **166** up after the dogs **170** get undermined brings the collets **206** on valve assembly **44** into narrow bore **40** that starts at **210** and ends at **212** in FIG. 8g. The collets **206** will need to go back through bore **40** to **210** and then the inner string **16** will need to be picked up to get the collets **206** back into bore **40** for the valve **44** to close.

[0041] The smart collet **42** has an array of flexible fingers **214** that have a raised section **216** with a lower landing shoulder **218**. There is a two position j-slot **220**. In one position when the shoulder **218** is supported, the j-slot **220** allows lower smart collet mandrel **222** that is part of the inner string **16** to advance until shoulder **224** engages shoulder **226**, which shoulder **226** is now supported because the shoulder **218** has found support. Coincidentally with the shoulders **224** and **226** engaging, hump **228** comes into alignment with shoulder **218** to allow the smart collet **42** to be held in position off shoulder **218**. This is shown in the metering and the reverse positions of FIGS. 5 and 7. However, picking up the inner string **16** gets hump **228** above shoulder **218** and actuates the two position j-slot **220** so that when weight is again set down the hump **228** will not ride down to the shoulder **218** to support it so that the collet assembly **214**, **216** will simply collapse inwardly if weight

is set down on it and shoulder **218** engages a complementary surface such as **212** in FIG. 8g.

[0042] Referring now to FIGS. 8i-j and FIGS. 10 a-b, the operation of the valve assembly **44** will be reviewed. FIGS. 10a-b show how the valve **44** is first rotated to close from the open position at run in and through various other steps shown in FIGS. 1-7. Spring **230** urges the ball **232** into the open position of FIG. 8j. To close the ball **232** the spring **230** has to be compressed using a j-slot mechanism **234**. Mechanism **234** comprises the sleeve **236** with the external track **238**. It has a lower triangularly shaped end that comes to a flat **242**. An operator sleeve **244** has a triangularly shaped upper end **246** that ends in a flat **238**. Sleeve **244** is connected by links **246** and **248** to ball **232** offset from the rotational axis of ball **232** with one of the connecting pins **250** to the ball **232** shown in FIG. 8j above the ball **232**.

[0043] The j-slot mechanism **234** is actuated by engaging shoulder **252** when pulling up into a reduced bore such as **40** or when going down with set down weight and engaging shoulder **254** with a reduced bore such as **40**. Sleeve **256** defines spaced collet fingers on the outside of which are found shoulders **252** and **256**. FIG. 10c shows one of several openings **258** in sleeve **256** where the collet member **206** is mounted (see also FIG. 8i). Pin **260** on the collet **206** rides in track **238** of member **236** shown in FIG. 10a.

[0044] At the start of metering shown in FIG. 5, the triangular components **240** and **246** are 90 degrees offset. Each time that shoulder **252** gets pulled up through a narrow bore like **40** all the way through, **236** is made to rotate 90 degrees. The same thing happens when shoulder **254** then is pushed down through a narrow bore like **40** all the way through. The first 180 degrees of rotation of **236** will still leave flats **242** and **248** misaligned. However, 270 degrees of rotation of **236** will align those flats and push sleeve **244** to turn ball **232** to the closed position while compressing spring **230**. The 270 degrees of motion of **236** to close ball **232** coincides with metering in FIG. 6 where the shoulder **252** gets pulled through bore **40** going up and then shoulder **254** gets pushed back down through the same bore **40** and then shoulder **252** gets pulled up through bore **40**. Of course the ball **232** can be opened after being closed as described above by pushing shoulder **254** back

down through bore **40** get the flats **242** and **248** misaligned at which time the spring **230** rotates the ball **232** back to the open position.

[0045] When the inner string **16** is pulled out the sleeve **114** will be unlocked, shifted and locked in its shifted position. Referring to FIG. 8j a series of shifting collets **252** have an uphole shifting shoulder **254** and a downhole shifting shoulder **256**. When the inner string **16** comes uphole the shoulder **254** will grab shoulder **258** of sleeve **260** shown in FIG. 8e and carry sleeve **260** off of trapped collet **116** thus releasing sleeve **114** to move uphole. Sleeve **260** will be carried up by the inner string **16** until it bumps shoulder **262** at which point the sleeve **114** moves in tandem with the inner string **16**. Since sleeve **114** is attached to ported sleeve **20** whose top end **264** is not restrained and is free to move up sleeves **114** and **20** will move in tandem with sleeve **260** until collets **266** land in groove **268** to allow sleeve **260** to go over collets **266** and shoulder **254** to release from sleeve **260** as the inner string **16** comes out of the hole. At this time sleeve **268** will block ports **20** from the annulus **22** so that a production string can go into the packer **18** to produce through the screens (not shown) and through the packer **18** to the surface. Going in the reverse direction the above described movements can be reversed to open ports **20**. To do that the inner string **16** is lowered so that shoulder **256** engages shoulder **270** on sleeve **260** to pull sleeve **260** off of collets **266**. Sleeve **114** and with it the sleeve with ports **20** will get pushed down until collets **116** go into groove **272** so that sleeve **260** can go over them and shoulder **256** can release from sleeve **260** leaving the sleeve **114** locked in the same position it was in for run in as shown in FIG. 8e. Sleeve **114** is lockable at its opposed end positions.

[0046] Referring now to FIGS. 11a-j, the squeeze position is shown. Comparing FIG. 11 to FIG. 8 it can be seen that there are several differences. As seen in FIG. 11e, the ball **300** has landed on seat **118** breaking shear pin **124** as the shifting of seat **118** allows the flapper **120** to close. The packer **18** has been set with pressure against the landed ball **300**. With the packer **18** set the work string **12** picks up the inner string assembly **16** as shown in FIG. 11a such that the jet tool **26** as shown in FIG. 11c now has its collets **50** sitting on the packer upper sub **72** where formerly during run in the top **90** of the jet tool

26 sat during run in as shown in FIG. 8b. With the weight set down on the inner assembly **16** the seal **52** is below ports **106** so that a return path **138** is closed. This isolates the upper annulus **56** (see FIG. 3) from the screens (not shown) at the formation. As mentioned before the j-slot **96** allows for alternative positioning of seal **52** below ports **106** for the squeeze position and for assumption of the circulation position of seal **52 being** above ports **106** on alternate pickup and set down forces of the inner string **16**. The position in FIG. 11d can be quickly obtained if there is fluid loss into the formation so that the upper annulus **56** can quickly be closed. This can be done without having to operate the wash pipe valve **44** which means that subsequent uphole movements will not swab the formation as those uphole movements are made with flow communication to the upper annulus **56** while fluid loss to the formation can be dealt with in the jet tool **26** by setting down with the j-slot **96** in the proper position.

[0047] It should also be noted that the internal gravel exit ports **30** are now well above the sliding sleeve **114** that initially blocked them to allow the packer **18** to be set. This is shown in FIGS. 11d-e. As shown in FIG. 3 and FIG. 11f, the metering dogs **170** of the metering device **38** are in bore **40** as is the smart collet assembly **42** shown in FIG. 11i. The wash pipe valve **44** is below bore **40** and will stay there when shifting between the squeeze and circulate positions of FIGS. 3 and 4.

[0048] FIG. 12 is similar to FIG. 11 with the main difference being that the j-slot **96** puts sleeves **98** and **100** in a different position after picking up and setting down weight on the inner string **16** so that the seal **52** is above the ports **106** opening a return path **138** through the ports **106** to the upper annulus **56**. This is shown in FIG. 12c-d. The established circulation path is down the inner string **16** through passage **82** and out ports **30** and then ports **20** to the outer annulus **22** followed by going through the screens (not shown) and then back up the inner string **16** to passage **138** and through ports **106** and into the upper annulus **56**. It should also be noted that the squeeze position of FIG. 11 can be returned to from the FIG. 12 circulation position by simply picking up the inner string **16** and setting it down again using j-slot **96** with the jet tool **26** supported off the packer upper sub **72** at collets **50**. This is

significant for several reasons. First the same landing position on the packer upper sub 72 is used for circulation and squeezing as opposed to past designs that required landing at axially discrete locations for those two positions causing some doubt in deep wells if the proper location has been landed on by a locating collet. Switching between circulate and squeeze also poses no danger of closing the wash pipe valve 44 so that there is no risk of swabbing in future picking up of the inner string 16. In prior designs the uncertainty of attaining the correct locations for the squeeze and circulation steps at times caused inadvertent release of the wash pipe valve to the closed position because the shear mechanism holding it open was normally set low enough that surface personnel could easily shear it inadvertently. What then happened with past designs is that subsequent picking up of the inner string swabbed the well. Apart from this advantage, even when in the circulation step of FIG. 12, the squeeze position can be quickly resumed to reposition seal 52 with respect to ports 106 to prevent fluid losses to the formation with no risk of operating the wash pipe valve 44.

[0049] It is worth noting that when the string 12 is picked up the jet valve 26 continues to rest on the packer sub 72 until shoulders 95 and 97 come into contact. It is during that initial movement that brings shoulders 95 and 97 together that seal 52 moves past ports 106. This is a very short distance preferably under a few inches. When this happens the upper annulus 56 is in fluid communication with the lower annulus 22 before the inner string 16 picks up housing 134 of the jet valve 26 and the equipment it supports including the metering assembly 38, the smart collet 42 and the wash pipe valve assembly 44. This initial movement of the sleeves 98 and 100 without housing 134 and the equipment it supports moving at all is a lost motion feature to expose the upper annulus 56 to the lower annulus 22 before the bulk of the inner string 16 moves when shoulders 95 and 97 engage. In essence when the totality of the inner string assembly 16 begins to move, the upper annulus 56 is already communicating with the lower annulus 22 to prevent swabbing. The j-slot assembly 96 and the connected sleeves 98 and 100 are capable of being operated to switch between the squeeze and circulate positions without lifting the inner string 16 below the jet valve 26 and its

housing **134**. In that way it is always easy to know which of those two positions the assembly is in while at the same time having an assurance of opening up the upper annulus **56** before moving the lower portion of the inner string **16** and having the further advantage of quickly closing off the upper annulus **56** if there is a sudden fluid loss to the lower annulus **22** by at most a short pickup and set down if the jet valve **26** was in the circulate position at the time of the onset of the fluid loss. This is to be contrasted with prior designs that inevitably have to move the entire inner string assembly to assume the squeeze, circulate and reverse positions forcing movement of several feet before a port is brought into position to communicate the upper annulus to the lower annulus and in the meantime the well can be swabbed during that long movement of the entire inner string with respect to the packer bore.

[0050] In FIG. 13 the inner string **16** has been picked up to get the gravel exit ports **30** out of the packer upper sub 72 as shown in FIG. 13e. The travel limit of the string **16** is reached when the metering dogs **170** shoulder out at shoulder **186** as shown in FIG. 13f-g and get support from humps **176** and **178**. At this time the smart collet shown in FIG. 13i is out of bore **40** so that when weight is set down on the inner string **16** after getting to the FIG. 13 position and as shown in FIG. 13i, the travel stop **224** will land on shoulder **226** which will put hump **228** behind shoulder **218** and trap shoulder **218** to shoulder **219** on the outer string **24** supported by the packer **18**. As stated before, the smart collet **38** has a j-slot assembly **220** shown in FIG. 13h that will allow it to collapse past shoulder **219** simply by picking up off of shoulder **219** and setting right back down again. By executing the metering operation and displacing enough hydraulic fluid from reservoir **190** shown in FIG. 13g the wash pipe valve **44** is pulled through bore **40** that is now located below FIG. 13j. Pulling valve **44** once through bore **40** turns its j-slot **234** 90 degrees but flats **242** and **248** in FIGS. 10a-b are still offset. Going back down all the way through bore **40** will result in another 90 degree rotation of the j-slot **234** with the flats **242** and **248** still being out of alignment and the valve **44** is still closed. However, picking up the inner string **16** to get valve **44** through bore **40** a third time will align the flats **242** and **248** to close the valve **44**. Valve **44**

can be reopened with a set down back through bore **40** enough to offset the flats **242** and **248** so that spring **230** can power the valve to open again.

[0051] The only difference between FIGS. 13 and 14 is in FIG. 13i compared to FIG. 14i. The difference is that in FIG. 14i weight has been set down after lifting high enough to get dogs **170** up to shoulder **186** and setting down again without metering though, which means without lifting valve **44** through bore **40** all the way. FIG. 14f shows the dogs **170** after setting down and away from their stop shoulder **186**. FIG. 14i shows the hump **228** backing the shoulder **218** of the smart collet **42** onto shoulder **219** of the outer string **24**. Note also that the ports **30** are above the packer upper sub **72**. The inner string **16** is sealed in the packer upper sub **72** at seal **108**.

We claim:

1. A well treatment method for squeezing and gravel packing, comprising;

running in an outer assembly that comprises a packer, an outer string supported by said packer and leading to at least one screen and further comprising at least one outer exit port between said packer and said screen;

supporting said outer assembly with an inner string assembly for run in where the inner string assembly is in turn supported on a running string and the inner string assembly comprises a crossover tool to selectively allow gravel to pass through the inner string and out toward said outer exit port of said outer assembly with returns coming through said screen and said crossover tool to an upper annulus defined above said packer and around said running string;

setting said packer to isolate a zone in a wellbore for said screen from said upper annulus and define a lower annulus;

defining a squeeze position for forcing fluid into the wellbore through said lower annulus, a circulate position where gravel is deposited in said lower annulus and returns come through said screen and past said packer to said upper annulus and a reverse position where gravel in said inner string above said crossover can be reversed out to the surface, by relative movement of at least a portion of said inner string with respect to said packer;

moving said inner string assembly to a supported single position off said outer assembly;

manipulating a ported valve assembly with said running string to selectively close or open said upper annulus from said lower annulus for said squeeze and circulate positions respectively while said inner string assembly remains supported in said single position.

2. The method of claim 1, comprising:

supporting said inner string assembly off said packer for said squeeze and circulate positions.

3. The method of claim 1, comprising:

connecting a housing of a ported valve assembly to said inner string assembly for support of said inner string assembly off said outer assembly;

manipulating a sleeve assembly with said running string with respect to said housing to selectively open or close a passage through said housing between said upper and said lower annuli.

4. The method of claim **3**, comprising:

using sequential pickup and set down movements of said running string to selectively open and close said passage.

5. The method of claim **4**, comprising:

landing said sleeve assembly at different positions with respect to said housing with cycles of picking up and setting down said running string.

6. The method of claim **5**, comprising:

using a j-slot assembly between said housing and said sleeve assembly to determine the landing position of said sleeve assembly with respect to said housing on successive cycles of picking up and setting down said running string.

7. The method of claim **6**, comprising:

providing a port on said housing located uphole of an external seal on said housing to seal against said packer;

providing a sleeve assembly seal on an exterior surface of said sleeve assembly that is selectively positioned on opposed sides of said housing port.

8. The method of claim **7**, comprising:

disposing said sleeve assembly seal in a passage between said sleeve assembly and said housing;

communicating said housing port with said upper annulus;

communicating said passage to said lower annulus.

9. The method of claim **8**, comprising:

blocking said passage when said sleeve assembly seal is below said housing port;

opening said passage when said sleeve assembly seal is above said housing port.

10. The method of claim **3**, comprising:

supporting said housing of said ported valve assembly off said packer.

11. The method of claim **10**, comprising:
 - providing a retractable biased collet adjacent to an exterior groove on said housing of said ported valve assembly;
 - retracting said collet to allow said collet to initially move through said packer;
 - biasing said collet out of said groove after moving it through said packer so that said collet can support said housing of said ported valve assembly and the balance of said inner string assembly that is supported by said housing of said ported valve assembly off said packer.
12. The method of claim **3**, comprising:
 - communicating said upper and lower annuli every time said running string raises said sleeve assembly.
13. The method of claim **3**, comprising:
 - raising said housing and with it said inner string assembly with said sleeve assembly only after movement of said running string beyond a predetermined distance needed to communicate said upper and lower annuli.
14. The method of claim **8**, comprising:
 - providing a seat in said sleeve assembly that accepts an object;
 - landing an object on said seat and building pressure;
 - operating a valve in said passage mounted below said sleeve assembly seal by shifting said seat.
15. The method of claim **14**, comprising:
 - opening at least one port into said passage below said valve due to said seat shifting;
 - pumping treatment fluid through said opened port and into said passage to direct said treatment fluid to the lower end of said inner string assembly while isolating said upper annulus.
16. The method of claim **15**, comprising:
 - applying a pickup force to said running string to remove said inner string assembly while pumping said treatment fluid;
 - directing said treatment fluid toward said screen as said inner string assembly is removed from said outer assembly.

17. The method of claim 1, comprising:
 - providing a wash pipe with a valve adjacent a lower end of said inner string assembly;
 - precluding operation of said wash pipe valve while moving said ported valve assembly between said squeeze and circulate positions.