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Jordan

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[54] **WELL GRAVELLING TOOL**

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[52] **U.S. Cl.** **166/51;** 166/236

[51] **Int. Cl.**[2] **E21B 43/04**

[58] **Field of Search** 166/51, 236

[56] **References Cited**

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3,134,439	5/1964	Shields, Jr.	166/51
3,627,046	12/1971	Miller	166/51
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3,818,986	6/1974	Abney et al.	166/51

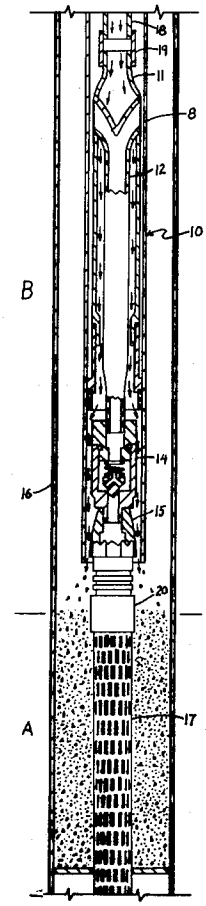
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[57] **ABSTRACT**

A well gravelling tool for operative engagement with a drill pipe string for use in the conveyance, positioning and gravel packing of a tubular member, e.g., a perforated tubular element, liner, screen, or the like, within a well via use of a water-gravel slurry passed downward through the drill pipe string to the well bottom. The tool comprises a pair of concentric tubular members, an outer large diameter tubular member, and an inner small diameter tubular member, between which an annulus is formed, which annulus is in open communication with the passageway leading to the surface through the drill pipe string. The inner small diameter tubular member opens through the wall of the larger diameter tubular member to the exterior, and the upper portion thereof is closed to the annular passageway. The lower extremity of the inner small diameter tubular member is provided with a check valve which permits ascent of liquid through the opening through the inner small diameter tubular member, but not downward flow. A tubular segment is located adjacent the check valve and on the lower extremity of the inner small diameter tubular member for operative engagement with the tubular member to be conveyed, positioned and packed within the well bottom. In operation, a water-gravel slurry is passed downwardly through the drill pipe string, the annulus between the concentrically mounted large and small diameter tubular members, and gravel is dispersed about the tubular element positioned at the bottom of the well. (Water flows through the gravel packing, into the tubular elements, and via the check valve through the small diameter tubular member and into the annulus located between the well casing and external wall of the pipe string to the surface.)

10 Claims, 4 Drawing Figures



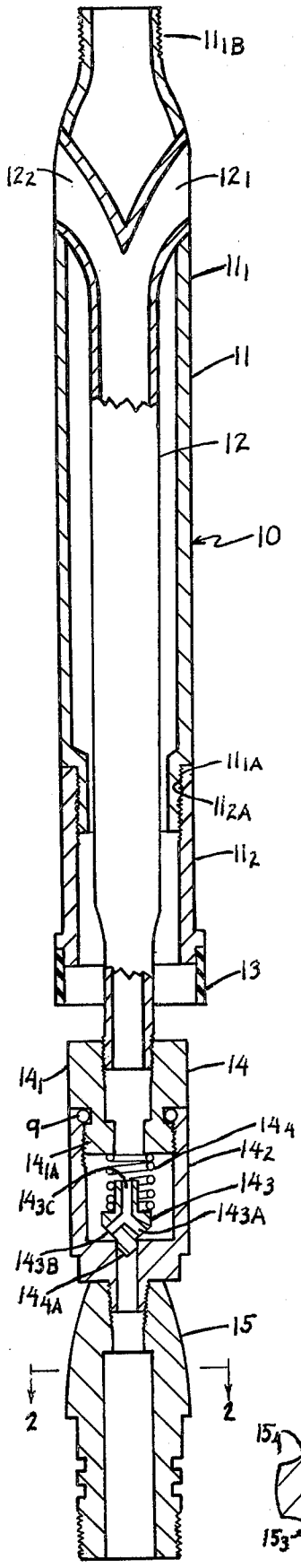


FIG. 1

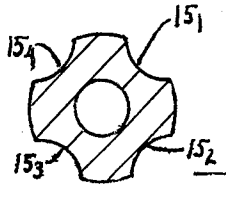


FIG 2

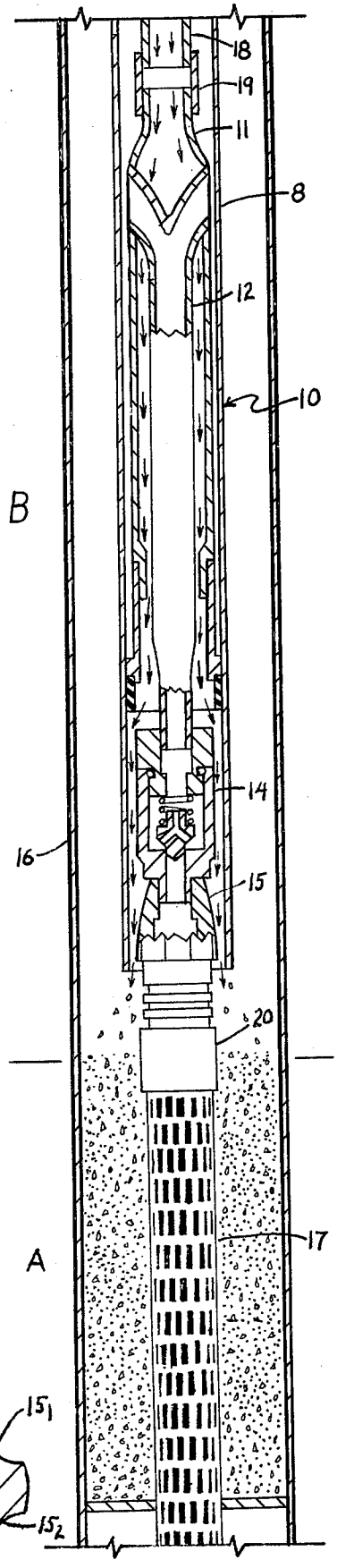


FIG. 3

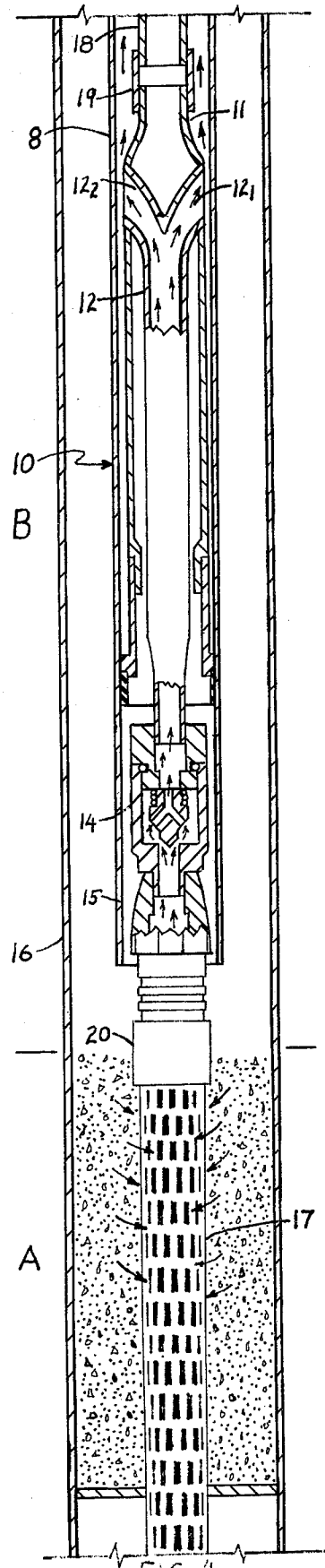


FIG. 4

WELL GRAVELLING TOOL

In drilling deep wells, it is conventional to position tubular shaped members, including blank pipes, foraminous liners, sand screens, and the like, within well bores at the locations of producing sand stratums. Typically, tubular shaped members, or blank pipes, are alternately placed with the sand screens, in series, one atop the other. Gravel is placed about such members to prevent caving, spillage, and influx of sand into the well.

Several types of gravel pack apparatus, or gravel pack systems, are known to the art. All are structured to provide means for depositing gravel about the outer face of the tubular elements, e.g., the screen or foraminous liner, while precluding deposition of gravel inside the liner. In certain systems, the gravel is contained within bailers, or containers, let down upon wire or cable from the surface to the well bottom. For example, apparatus of such type is described in U.S. Pat. No. **2,140,072** granted to R. L. Chenault. A cable conveyed container, for retention of the gravel, is provided with valve means adjacent the bottom of the container. The valve is constructed so that the gravel filled container is normally closed to retain the gravel, but is adapted to open on contact of the bottom of the container with the liner about which gravel is to be packed. Another apparatus of such general character is described by U.S. Pat. No. **3,182,723** granted to W. K. Layne, Sr. This device is also characterized as a cable-conveyed bailer beneath which is suspended a smaller diameter double-end conical shaped baffle device, a lower end of which is to contact and block off the liner to the flow of solids while the upper end is employed to better distribute the gravel upon its release from the bailer. The bailer is provided with a frangible disk upon which the gravel rests, and adjacent thereto is provided a remotely controlled explosive cap. The explosive cap is set off from the surface to rupture the frangible disk and release gravel from the bailer. While these and other such devices have proven useful for the purposes intended, all are too complex. One major difficulty, particularly with the bailer type devices, is that considerable time is required for the many "trips" down the well bore. The necessity of the many incremental releases of gravel and the great number of repetitive steps involved in gravel packing is unduly burdensome. Moreover, it is necessary to make very accurate and exact calculations in discharging gravel into a well for there is no way to return excess gravel resulting from overfills. Less complex devices, capable of more rapid operation, but yet capable of a high degree of precision by ordinary operating labor, are needed.

In another type of well gravelling system, such as the hydraulic packing system described by U.S. Pat. No. **2,372,461** granted to L. C. Uren, the lower portion of the well bore is capped off, the top of the liner is temporarily plugged, and a gravel slurry is pumped downwardly from the surface through a string of tubing, which encloses the liner. The slurry is passed downwardly, through the annular opening between the tubing and the liner, and out the lower terminal end of the tubing. The gravel settles within the cavity or annular space between the well wall and the liner, and liquid ascends through the annulus between the well wall and the said tubing to the surface.

The well gravelling tool described in D. C. Smith's U.S. Pat. No. **3,630,277** has proven particularly suitable for use in gravel packing. The well gravelling tool described therein comprises a pair of concentric members, a smaller diameter member mounted within a larger diameter tubular member, providing an annular opening which is communicated to the opening through the drill pipe string. The drill pipe string and well gravelling tool are operatively engageable, e.g., via threadable connections one member with the other, and the well gravelling tool, in turn, is engageable, e.g., via threadable connection, of opposite cast, with a tubular member located within the bottom of the well to seal the interior of the latter from entry of fluid or gravel. Gravel is discharged downwardly from the surface through the drill pipe string and well gravelling tool to fill the annulus of the well outside the tubular element. Water, in a second discrete step, is forced down into the well to pack the gravel and pick up any excess which is returned to the surface with the water which ascends through the well gravelling tool and drill pipe string. Whereas this tool has proven admirably suitable for packing wells, the present invention is nonetheless an improvement thereover.

Accordingly, the primary object of the present invention is to provide a new and novel well gravelling tool, characterized particularly as one wherein the gravel is dispersed as a slurry, and the gravel thereof packed around the tubular element located in the well bottom, while simultaneously the water is returned to the surface.

A further object is to provide a new and novel well gravelling tool of simplified construction, one which is easily serviced, easily operated, and capable of packing wells with considerable economy.

These objects and others are achieved in accordance with the present invention comprising a well gravelling tool for use in combination with a drill pipe string. The well gravelling tool is secured upon, and operatively engaged with, a drill pipe string, and so positioned on the drill pipe string it can be used to lower a tubular member, e.g., a liner or screen, into a well or well casing wherein the tubular member can be attached to other tubular members of a series positioned in the well bottom and packed in the bottom of the well within an oil producing stratum to provide a path for oil flow from the formation through the pack and the series of aligned tubular members into the drill string. In packing the gravel about the tubular member, a water-gravel slurry is passed downwardly from the surface via the drill pipe string through a first conduit within the well gravelling tool, and water returned from the bottom of the well to the surface via a second conduit within the well gravelling tool, the water after passage through the well gravelling tool ascending within an annulus between the production tubing and the outer surface of the drill pipe string.

The well gravelling tool is comprised generally of a pair of concentric tubular members, an outer tubular member of relatively large diameter inside which the inner smaller diameter tubular member is mounted. The upper end of the inner smaller diameter tubular member is opened through the wall of the outer tubular member to the exterior, while being closed to the tubular opening through the outer tubular member. The relative diameters of the outer and inner tubular members are such as to provide an annular opening which ex-

tends from the top of the outer tubular member downwardly therethrough, the annulus forming a separate and distinct passageway from that which extends through the tubular opening within the inner tubular member. The lower terminal end of the inner tubular member is preferably extended beyond the lower terminal end of the annular passageway and, preferably also, a check valve mounted thereon closes the tubular opening of the inner tubular member to flow in a downward direction, but leaves the tubular opening open to upward flow. The lowermost portion of the inner tubular member, or at a location below the check valve, there is provided a tubular element for operative engagement with a tubular member to be positioned within the well. In its most preferred form, the tubular element is provided with an externally threaded lower end which permits coupling of the lower end of the tool via a threaded union to a tubular member of the type to be packed within the well bottom. In a preferred embodiment also, the upper terminal end of the tool comprising the outer tubular member, generally of reduced cross-section, is externally threaded for threadable engagement, e.g., via a union connection, to a drill pipe of a drill pipe string.

In operatively positioning the tool for service, the upper end of the tool is operatively engaged to a drill pipe string, and the lower end of the tool to a tubular member to be packed in the well. After the time that the tubular member has been positioned at the bottom of the well and is ready for packing, a preselected amount of gravel contained in a water-gravel slurry is passed downwardly under pressure through the drill pipe string and through the annular passageway through the tool such that the gravel is spread around the tubular element and packed. The water, which is separated from the slurry, simultaneously enters into the path formed by the train of packed tubular members and ascends therethrough, through the check valve and into the tubular opening of the inner tubular member, and exits near the upper end of the tool into the annulus between the production tubing, the outer wall of the outer tubular member and drill pipes and ascends to the surface.

These and other features and advantages will be better understood by reference to the following detailed description and to the accompanying drawings to which reference is made in the description. Subscripts are used to denote the sub-components of a larger subassembly of the tool. Subscripts are dropped in the written description, where the reference is intended in generic sense.

Referring to the drawings:

FIG. **1** is a section elevation view depicting a preferred well gravelling tool.

FIG. **2** is a plan view, taken along section **2—2** of FIG. **1**, depicting a structural detail of the preferred well gravelling tool.

FIGS. **3** and **4** are elevation views in partial section illustrating the manner in which the well gravelling tool is mounted on a drill pipe string and its interrelationship with a tubular member which has been located at the bottom of a well, inclusive of the technique of using a water-gravel slurry in dispersing and packing gravel around the tubular member. For convenience, since both occur simultaneously, the path of distribution of the gravel is depicted in the first figure of this series, and the path of flow for water removal in the latter figure.

Referring to FIG. **1**, there is shown a preferred gravel packing apparatus or well gravelling tool **10** which, in operative engagement with a drill pipe string, can be used for gravel packing a well. The well gravelling tool **10** is constituted generally of an outer tubular casing **11**, a portion of which is of relatively large diameter, an inner tubular casing **12** of relatively small diameter concentrically mounted within the outer tubular member **11**, preferably a one-way flow valve **14** mounted upon a lower terminal end of a projecting portion of the inner tubular casing **12**, and a tubular fitting **15** fitted on the lower end of the valve **14**.

The outer tubular member **11** can be made as a unitary tubular member, or fitted together from a plurality of tubular segments of uniform outside diameter, i.e., segments 11_1 and 11_2 as depicted in the drawings. Lower tubular segment 11_2 is thus adjoined to or threadably engaged to upper segment 11_1 via internal threads 11_{2A} which mate with external threads 11_{1A} on the smaller diameter projecting lower end of tubular segment 11_1 of outer tubular segment **11**. The extreme lower end of tubular member **11** (or tubular segment 11_2) is, in preferred embodiments, provided with an elastic seal **13** of tubular shape which fits upon a lip located at the terminal end of the tubular member **11**. The seal **13**, in turn, fits against the surrounding production tubing of a producing well to close and seal the annulus formed between the external wall which forms outer tubular member **11** and the internal wall which forms the production tubing. The top of the inner tubular member **12** is open to the exterior of the outer tubular member via an opening, or openings 12_1, 12_2, through the wall of outer tubular member **11** at locations just below the externally threaded upper reduced segment 11_{1B} thereof from which the tool **10** can be adjoined, e.g., via an appropriate union to a pipe of a drill pipe string. The inner tubular member **12**, as stated, is fitted concentrically within the larger diameter outer tubular member **11** and sufficient clearance is provided between the external wall of inner member **12** and the inside wall of outer member **11** to provide an annular passageway which, despite the minor obstructions offered by the wall segments of inner member **12** at the location of openings 12_1 , 12_2, leads from the opening at the very top or apex of outer tubular member **11** (at location 11_{1B}) to the opening at the bottom of outer tubular member **11** (at the location of elastic seal **13**).

A check valve, or one-way flow valve **14**, in accordance with a preferred optional feature, is operatively secured upon and adjoined to the lower projecting tapered end of inner tubular member **12**. The valve **14** is constituted of a valve body comprising adjoined tubular segments 14_1, 14_2 within which is fitted a spring biased gate opening 14_3. The valve **14** is thus constituted of an upper body comprising tubular segment 14_1 provided with an externally threaded lower shank portion 14_{1A}. The inside of the upper larger portion 14_1 is tapped and internally threaded, by virtue of which the valve **14** can be threadably engaged upon and upon and secured to an externally threaded portion of the lower (reduced diameter) terminal end of inner member **12**. The lower body portion of the valve **14** is constituted of a tubular member 14_2, the upper internal portion of which is threaded for mating or threadable engagement with the externally threaded lower shank portion 14_{1A}

of upper body portion 14_1 of valve **14.** The members are sealed together via a protective O-ring **9** which is seated between contacting surfaces. The lower body portion of valve **14,** i.e., tubular member 14_2, is partially enclosed by a bottom wall, but contains an externally threaded tubular projection which is threadably engaged with, and secured upon, a tubular fitting **15.** A gate 14_3 provided with a plurality of openings 14_2A, 14_{3B} leading into a main opening 14_{3C}, is seated within the lower portion of tubular member 14_2, and a projected upper portion thereof is fitted within a helical spring 14_4 such that its lower end 14_{4A} can be seated and unseated within the channel which leads into the axial opening through inner tubular member **12.** The upper end of tubular fitting **15,** this end of which is frusto-conic shaped with its tapered end upward, is internally threaded and threadably engaged with the lower externally threaded projection of valve **14,** and the lower end thereof is externally threaded for threadable engagement with a tubular element such as located at the bottom of a well to be packed.

The external side wall of the tubular fitting **15** is preferably serrated, or ridged by a plurality of even spaced, longitudinally oriented grooves, in this instance four in number, 15_1, 15_2, 15_3, 15_4, as shown by reference to FIG. **2.** The function of these grooves is to prevent or suppress bridging of particles between the outer walls of the tubular fitting **15** and the inside walls of the well casing.

Referring to FIGS. **3** and **4,** there is shown a borehole or well **16** which extends through the earth B into a producing formation A from which oil is to be taken. A perforated metal casing is located within and aligns the borehole or well **16** to prevent cave-ins such as can occur at locations wherein the well passes through loose or weak formations of earth. In packing a well **16,** a perforated liner or screen **17** is lowered via the drill pipe string through the casing and substantially concentrically aligned therewith, and gravel is packed within the annulus between the external surface of the screen **17** and the internal side of the wall of the casing.

In the operation of packing a well **16,** the tool **10** is used in the following manner: The tool **10,** at the surface, is secured via its upper threaded end 11_{1B} to the lower end of a drill pipe **18** of a drill pipe string. These members **10, 18** are preferably threadably secured each to the other via threadable engagement to a union connection **19,** right handed threads generally being employed to couple these members together. A screen **17** is next secured upon the lower end of the tool **10** via connection to the tubular fitting **15.** The members **15,** 17 are preferably threadably secured one to the other via threadable engagement to a union connection **20.** Left handed threads are employed to couple these members **15, 17** one to the other. The coupled members, which include the pipe **18** of the drill pipe string, the tool **10** (with its component parts), and the screen **17,** are then lowered through production tubing **8** into the well **16,** as shown by either of FIGS. **3** or **4,** until the lower end of screen **17** contacts a union (not shown) mounted on the upper end of a previously attached pipe blank (not shown) at which time the assembly is rotated in counterclockwise direction to produce threadable engagement and secure the screen **17** upon the pipe blank.

A water-gravel slurry is next introduced at the surface into the pipe string, the slurry descending as shown by reference to FIG. **3,** through pipe **18** via the outer tubular member **11,** and through the annulus between outer tubular member **11** and inner tubular member **12.** The water-gravel slurry is discharged from the lower terminal end of outer tubular member **11,** the gravel being deflected radially outwardly by contact with the upper end of tubular fitting **15,** gravitating downwardly and being spread about the circumference of screen **17** filling the annulus between the outer surface of screen **17** and the casing forming a wall inside the well **16.**

As the gravel is accumulated about the screen **17,** within the annulus between the outer surface of the screen **17** and the casing of the well **16,** the water separates therefrom and enters into the screen **17** via the perforated surface thereof and ascends, as shown by specific reference to FIG. **4,** through the tubular fitting **15,** passes through the check valve **14,** and enters into the axial opening through inner tubular member **12.** The water passes upwardly through inner tubular member **12** and egresses therefrom via the upper opening 12_1, 12_2 after which time it ascends to the surface via the annulus formed between the production tubing **8** and pipe **18** and the drill pipe string which lies within the casing of the well **16.**

In the practice of packing a well, an amount of gravel approximately or nearly equal in amount to that required to pack the annulus between the outer face of the screen **17** and the casing of the well **16** is measured out, and slurried in water, and the slurry then pumped downwardly through the drill pipe string. In the operation, when the gravel has filled the annulus, pressure builds up and back pressure indicates that the gravel has reached the tool, this occurring perhaps at a pressure ranging from about **800** to about **1000** psig, or higher, this providing a tight, secure pack.

The annulus between screen **17** and the casing of the well **16** thus packed, the drill pipe string is next rotated counterclockwise to uncoupled the well gravelling tool **10** from the union **20** of screen **17.** The assembly comprised of a drill pipe string, inclusive of pipe **18,** and well gravelling tool **10** is then withdrawn to the surface and the operation repeated ad infinitum until the packing of the well is completed.

It is apparent that various modifications and changes, such as in absolute or relative dimensions of the parts, materials and components of the well gravelling tool can be made without departing the spirit and scope of the invention as will be apparent to those skilled in the art.

The tool of this invention can be used to pack through, e.g., **2** inches tubing to any size casing available for use in well completion.

Having described the invention, what is claimed is:

1. Apparatus characterized as a well gravelling tool for operative attachment to the terminal end of a drill pipe string for use, with production tubing, in the conveyance, positioning and gravel packing of a tubular member within a well via use of a water-gravel slurry which, in combination, comprises:

a pair of concentric tubular members,

a large diameter single wall tubular member with means located at the enclosing upper wall thereof for operative engagement and open communication with the lower wall end of a pipe at the terminus of a drill pipe string.

a small diameter tubular member mounted within said large diameter tubular member, the upper end of which is permanently opened through the wall of the large diameter tubular member to the exterior and closed to the opening through the large diameter tubular member,

a fixed elastic seal of tubular shape externally fitted upon the large diameter single wall member for tight engagement with the production tubing within which the apparatus is conveyed,

means located on the lower extremity of said small diameter tubular member for operative engagement with the upper end of the tubular member positioned in the well,

whereby the apparatus can be conveyed via the production tubing into the well, a water-gravel slurry can be passed downwardly from the surface through the drill pipe string, through the large diameter tubular member, and the annulus between the pair of concentric members constituting the well gravelling tool, and gravel dispersed and packed under pressure about the annulus of the tubular member positioned in the well, water passed through the packing into the positioned tubular member and upwardly through the opening of the small diameter tubular member, and into an annulus formed by the outer wall of the pipes constituting the drill pipe string where it ascends to the surface, the apparatus detached from the tubular member now in place, and the drill pipe string and apparatus returned without any necessity of withdrawing the production tubing.

2. The apparatus of claim **1** wherein the upper terminal end of the large diameter tubular member is threaded for operative engagement to the lower terminal end of the drill string, and the lower terminal end of the tubular element is threaded with threads of opposite cast for engagement with the upper end of the tubular member positioned within the well.

3. The apparatus of claim **2** wherein the threads of the large diameter tubular member are right hand threads, and those on the lower terminal end of the tubular element are left hand threads.

4. The apparatus of claim **1** wherein the upper terminal end of the large diameter tubular member is of reduced cross-sectional diameter and externally threaded, the small diameter tubular member concentrically mounted therein is bifurcated at the top such that the terminal ends thereof which provide openings which extend to the exterior are about **180°** apart and the lower end thereof extends beyond the confines of the terminal end of the large diameter tubular member.

5. The apparatus of claim **1** wherein the lower terminal end of the large diameter tubular member is provided with a lip within which the tubular elastic seal is circumferentially seated.

6. The apparatus of claim **1** wherein a check valve is located upon and operatively communicated with the opening through the small diameter tubular member, the opening through small tubular member permitting upward flow but not the downward flow of water, and the means located on the small diameter tubular member at the lower extremity of said tool comprises a tubular element.

7. The apparatus of claim **6** wherein the upper end of the tubular element located below the check valve and on the lower extemity of said small diameter tubular member is of frusto-conic shape with the tapered end faced upwardly, and the opposite lower end thereof is threaded.

8. The apparatus of claim **7** wherein the lower end of said member is provided with left hand threads.

9. The apparatus of claim **7** wherein the outer larger diameter sides of the straight side portion of said member is provided with a plurality of spaced apart longitudinally oriented grooves.

10. The apparatus of claim **9** wherein there are four grooves, each spaced **90°** apart one from another.

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