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[54] **WELL BLOWOUT CONFINEMENT WITH DENSE BALLS**

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[52] **U.S. Cl.** **166/290,** 166/77

[51] **Int. Cl.** **E21b 43/00**

[58] **Field of Search** .... 166/77, 90, 290, 166/311, 312; 169/2 R, 2 A

[56] **References Cited**

UNITED STATES PATENTS

3,116,793	1/1964	McStravick	166/77 X
910,295	1/1909	Layne	166/90
1,520,288	12/1924	Featherstone	169/2 R
1,807,498	5/1931	Teed	169/2 R

OTHER PUBLICATIONS

World Oil Vol. 158 No. 4 March 1964.

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[57] **ABSTRACT**

In confining an outflow of fluid from a blowing or wild well, a fluid-confining conduit is extended to form a fluid connection at a selected intermediate depth within the well and utilized to inflow fluid and fluid-transported relatively large dense particles or balls that form a relatively dense and low permeability fluidized bed or mass of particles that effectively confines the outflow of gas.

8 Claims, 4 Drawing Figures

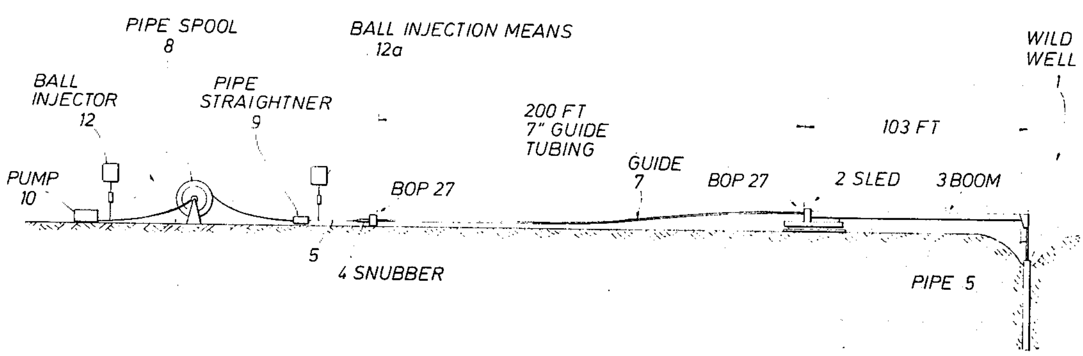


FIG. 1

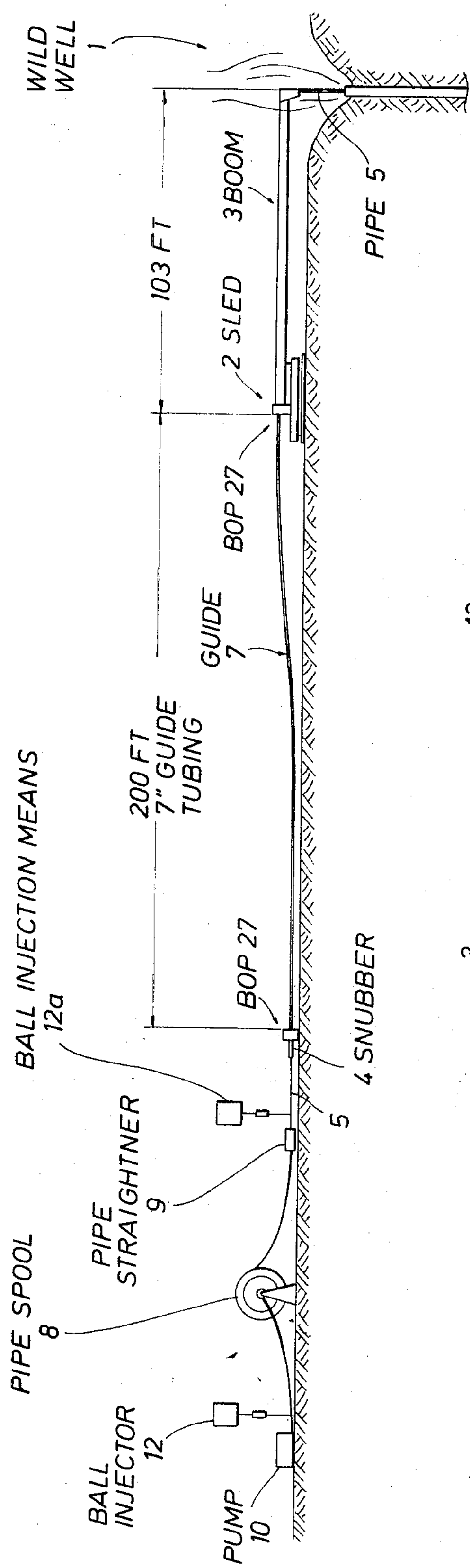
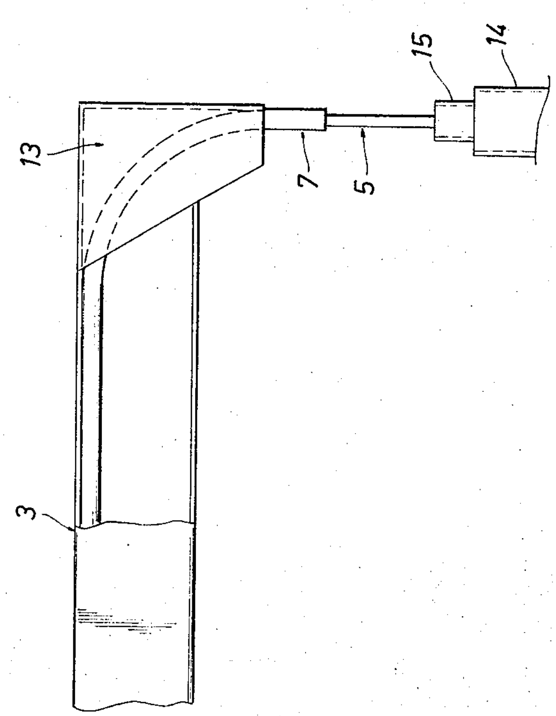


FIG. 2



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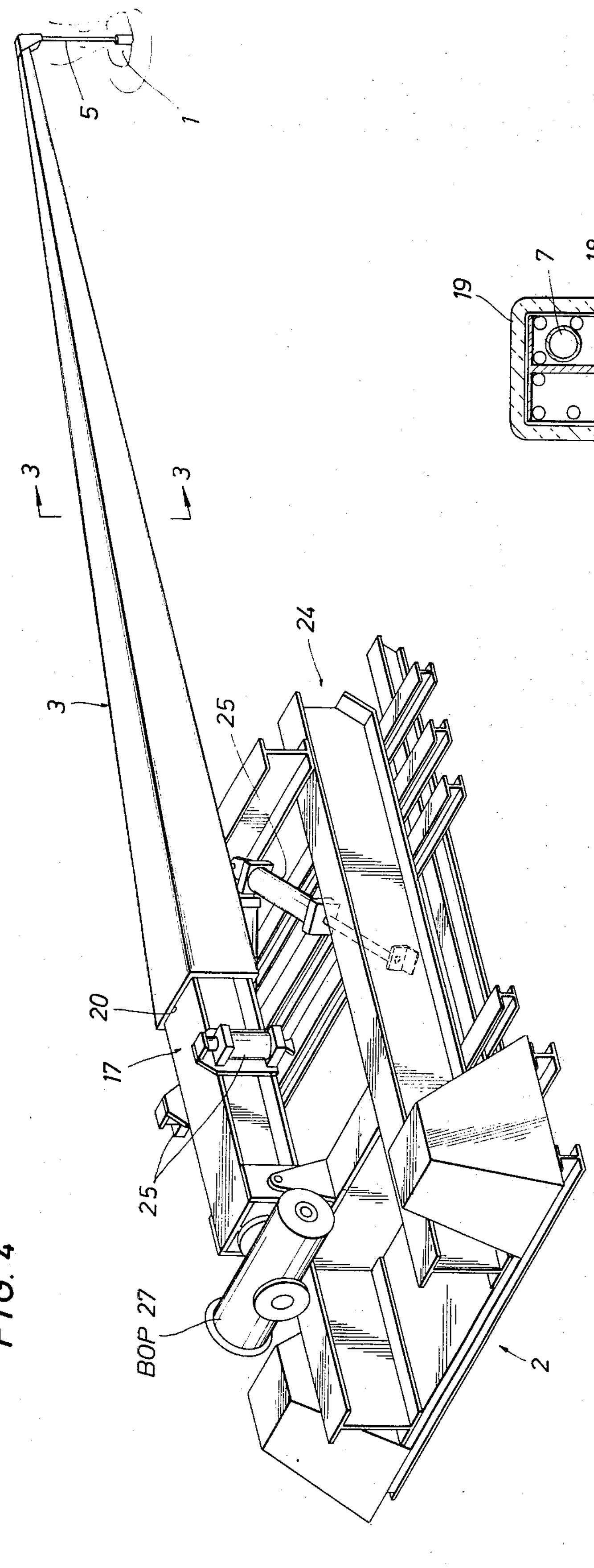

FIG. 4

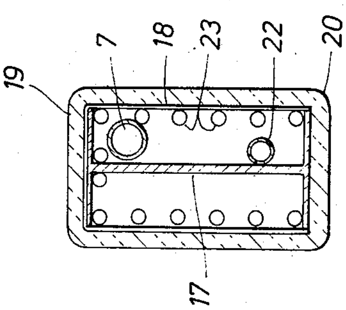

FIG. 3

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WELL BLOWOUT CONFINEMENT WITH DENSE BALLS

BACKGROUND OF THE INVENTION

This invention relates to a method of confining a flow of a relatively low density and/or substantially gaseous fluid from a borehole that opens into a relatively highly pressured reservoir from which such a fluid is escaping through a blownout or wild well. Such fluids are often gases, or gases containing entrained portions of liquid, and have relatively low densities. In near surface locations the escaping fluids have relatively high velocities are apt to be toxic and/or combustible and/or burning.

Numerous procedures for confining flows of fluids from wild wells have been previously porposed. Such prior proposals have included: hoisting, dragging, or pushing of a massive structure containing an open valve to position it to seal around the exposed conduits or seal against the crated earth near the wellhead; extending a laterally displaced fluid-confining conduit into fluid communication with a lower portion of the borehole of the wild well (or, more often, into the reservoir from which the fluid is escaping) by directionally drilling a relief well into an intersection with the borehole of the wild well and/or an adjacent portion of the reservoir; fracturing a nearby well to extend a horizontal fracture into intersection with the borehole of the wild well; or the like. Such conduits have usually been extended to relatively deep depths at which the velocity of the outflowing gas is low enough to permit pumping in enough relatively dense fluid to form a column of liquid capable of confining the fluid escaping from the reservoir. In general, such prior procedures have required disadvantageously long times to attain a deeply located fluid communication in or near the reservoir formation to allow a fluid such as a brine, a drilling mud, a cement, or the like to be injected in a manner that is effective in terminating the outflow. Unless the point of communication is adequately deep, such fluids are blown out of the wild well and provide some throttling but no confining of the outflowing fluid.

SUMMARY OF THE INVENTION

In the present invention, a flow of low density fluid from a wild well is confined by a combination of steps. A relatively unrestricted fluid-confining conduit is extended from a surface location to a selected intermediate depth within the well. Fluid having a density exceeding that of the fluid blowing from the well is inflowed into the borehole of the wild well by pumping it through that conduit. The location of the selected intermediate depth to which the conduit is extended is correlated with density of the inflowed so that, at the selected intermediate depth, the inflowing of the relatively dense fluid reduces the effective particle lifting energy of the outflowing to an amount that is insufficient to lift relatively large dense particles that can be entrained in and transported by the inflowing fluid. And, such relatively large dense particles are injected into the stream of inflowing fluid so that they are transported into the well to form a relatively low permeability mass or bed that restricts the outflow rate to one that can be terminated by inflowing enough to substantially fill the borehole of the wild well.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic illustration of an arrangement of equipment in and around a wild gas well;

FIG. 2 is an enlarged view of a near well portion of equipment shown in FIG. 1;

FIG. 3 is an enlarged cross-section of a boom portion of the equipment shown in FIG. 1; and

FIG. 4 is an enlarged view of a skid mounted portion of the equipment shown in FIG. 1.

DESCRIPTION OF THE INVENTION

FIG. 1 shows a wild well 1 through which there is an uncontrolled escape of substantially gaseous fluid that may be toxic and/or combustible and/or burning. Sled 2 on which boom 3 is mounted is skidded into a position that locates the boom end over the well. Snubber 4 is positioned to push or pull pipestring 5 (such as a 2⅞ tubing string) through a guide tube 7 (such as a 7 inch casing string) that extends to and along the boom 3. The slide and snubber are preferably positioned away from the well by significant distances such as those shown. Pipe 5 comprises a continuous string of tubing adapted to be fed from spool 8 and straightened by pipe straightener 9 as it is advanced by the snubber 4. Pumping means 10 is connected to pump fluid through pipe 5 at least during and after its advance. A ball injector means 12 and, where desired, an alternate ball injector means 12*a*, is arranged to be connected into pipe 5 to inject relatively large, dense particles of solid material into a stream of fluid being pumped through pipe 5. The alternate means 12*a* is connected by hot-tapping pipe 5 after it has been inserted.

As shown in FIG. 2, the near well portion of guide tube 7 is arranged and held in a substantially 90° bend having a relatively large radius (such as a 5 foot radius) by mounting means such as knee brace 13. The guide tube thus guides pipe 5 from a horizontal to a substantially vertically downward advance into well conduits, such as an outer casing 14 (e.g., a 13⅜ inch casing) and an inner casing 15 (e.g., a 9⅝ inch casing).

As shown in FIG. 3, the boom 3 is preferably formed from an I-beam 17 with attached stiffeners 18, a cover 19, and insulation 20. The guide tube 7 and water cooling tubes, such as water input tube 22 and water outlet tubes 23, are preferably mounted along boom 3 and connected to a cooling water circulating means (not shown).

As shown in FIG. 4, the skid mounting means for the boom 3 can comprise frame 24 containing vertical lift and lateral movement hydraulic cylinders 25. One or more blowout preventers 27 (see FIG. 1) are preferably connected to the guide tube 7 in order to control any high pressure fluid which might be caused to backflow through the guide tube.

Such an arrangement of tubing inserting equipment can be assembled by means of techniques and equipment which are commercially available. Such an arrangement provides a preferred means for extending a relatively unrestricted fluid confining conduit from a surface location to a selected intermediate depth location within a wild well. The inserted tubing string provides a significant amount of flow resistance within the borehole of the wild well and its insertion reduces the rate at which fluid is outflowing at the depth to which the tubing is extended.

The tubing string insertion is a particularly advantageous way of extending a conduit from a surface location to a selected intermediate depth within the wild well. Each foot of inserted tubing provides a determinable increment of additional throttling and each foot of insertion advances the lower end of the tubing into a zone of lower lifting energy. The inflowing of relatively high density fluid through the inserted tubing string provides an additional amount of throttling. These effects are cumulative and are preferably correlated to relatively quickly establish a fluid inflow into the wild well at a point at which the lifting energy of the outflowing fluid is low enough to be substantially controlled by injecting a bed of large dense particles.

The sled 2 is pushed and/or pulled toward well 1 and boom 3 is moved vertically and/or laterally until pipe 5 can be thrust into the borehole of the well by the pipe advancing action of snubber 5. Pipe 5 is lowered to a depth at which the effective lifing energy of the fluid escaping from the well is relatively near to or is less than an amount capable of lifting a relatively large dense particle (such as particles having a density and shape equivalent to those of lead balls of at least about ⅛ inch diameter.) Pipe 5 thus provides a fluid confining conduit extending between pumping means 10 and a selected intermediate depth within the wild well.

Instead of, or in addition to such an insertion of a pipe string, a relief well can be drilled into a near intersection (or an actual intersection) with the bore of the wild well at such a selected depth. The relief well can then be opened into fluid communication with the wild well, for example, by casing the relief well borehole adjacent to the wild well and perforating to form a perforation tunnel extending between the boreholes; by fracturing and/or underreaming and/or washing out the formations intervening between the boreholes; or the like procedures. Various procedures can be used as long as a relatively unrestricted fluid confining conduit is extended via the relief well borehole from a surface location to the selected depth within the borehole of the wild well.

The present invention is at least in part premised on a discovery that, in a wild well through which a relatively low density fluid is escaping from a highly pressurized reservoir, it is mechanically and economically feasible to confine the outflowing fluid by injecting, at an intermediate depth, large dense particles that fall into a flow restricting mass or form an increasingly dense fluidized bed that subsequently collapses into such a flow restricting mass at a lower depth within the well.

With respect to spherical particles falling through a motionless fluid of a given density (or remaining stationary with an upward flowing fluid) the force on the particles due to the relative velocity between the fluid and the particles is counter-balanced by the gravitational force on the particles (less the buoyant force of the fluid surrounding the particle). In a given wild well situation, the number, size and location of the casing strings, the length and dimensions of open hole, and the like are factors to be considered. In a uniformly sized hole the effective lifting energy of the outflowing gas is proportional to the mass times the velocity squared and decreases with depth (since the volume of the outflowing fluid increases, particularly when the fluid is gaseous, as it approaches the surface, where the pressure is less).

With respect to a spherical particle of given density, the tendency to fall through an upflowing fluid increases with increases in the diameter of the particle. However, in the transporting of fluid-entrained solid materials through a tubing, the tubing size must be correlated with the particle size to permit the flow of the particles (at a selected minimum acceptable rate of injection) without causing a bridging and screening-out of the particles.

The particles used in the present invention should be relatively large, and should have diameters, e.g., at least greater than about one-eighth inch, exceeding the diameters of particles suspended in drilling muds, cement slurries, or the like. The particles should be relatively dense and should have specific gravities, e.g., at least greater than about 3, and shapes, e.g., generally spherical, causing them to fall relatively rapidly through fluids such as water or less dense fluids. Lead balls are particularly suitable but such particles can include iron, steel, zinc, bismuth, etc. metals, minerals such as barite, anglesite, hematite, etc. The particles inflowed into the wild well can advantageously be mixed in composition and size. The presence of at least some relatively soft particles such as lead is desirable.

Where a string of tubing is injected into the wild well, the tubing is preferably as large as can feasibly be run into the smallest casing present in the wild well. The tubing inner diameter (ID) is preferably correlated with the particle outer diameter (OD) so that the tubing ID is at least about 5 percent larger than the OD of the largest diameter.

In a preferred procedure for practicing the present invention, the first injected particles are mainly or entirely composed of particles that have a shape and density at least substantially equivalent to those of lead spheres having a diameter of at least about one-fourth inch. If such particles are to fall or to remain unentrained by the outflowing gas, they must be injected deep enough within the well to encounter a relatively low gas velocity due to the back pressure encountered by the outflowing gas. As mentioned above, the insertion of a tubing string causes a significant increase in such a back pressure. Alternatively or additionally, the back pressure above a selected depth can be increased by pumping in a fluid (which can comprise a suspension) having a density greater than that of the outflowing gas. Although such an inflowing fluid may be entrained and carried out by the gas, the additional pressure drop required to transport that material provides a back pressure that can reduce the velocity of the outflowing gas to one allowing the relatively large dense particles to fall below the point of injection or remain substantially suspended in a fluidized bed. In such a fluidized bed, the accumulating particles tend to remain fluidized until some critical amount has been added. During the fluidization each increment of the pressure drop remains roughly that required to counterbalance the particle weight per unit area. As more particles are added, a concentration is reached at which the entire suspension collapses and falls to the bottom (or to a restricted portion) of the borehole. This builds up a packed bed (or dense mass of adjacent particles) that has a relatively large resistance to flow. Due to the reduced rate of gas flow smaller particles can be added, so that the gas flow is eventually choked off, since the permeability of such a mass decreases with decreases in particle diameter. In a particular preferred embodiment, the relatively large, dense particles are injected in a graded sequence of slugs of incrementally decreasing sizes.

The insertion of a commercially available spoolable continuous tubing string is a particularly desirable procedure, since the insertion itself provides a significant back pressure, and a tubing string such as a 2⅞ inch tubing string provides a substantially completely unrestricted passage for spheres having diameters as large as about 2¼ inches. Tests were made of the capability of a commercially available snubber unit, such as a workover tubing inserting unit, to push a 2⅞ inch pipe string through a 7 inch casing string that curves around a 5 foot radius bend through an arc of 90°. The forces required to accomplish this were in the order of 5,000 to 6,000 pounds. The tests provided indications that it is mechanically feasible to push a tubing string around such a bend and guide the advancing tubing into a 9⅝ inch well casing, located below the guide tube by a distance in the order of 18 feet or more.

Relative to the initiation of prior wild well control procedures, the present process for the intermediate depth injection of dense large particles (such as lead balls) can be started relatively soon. In addition, as compared to the cost of drilling relief wells to the total depth and the installation and use of long duration pollution control equipment, the cost of the present procedure is reasonable. In a well that contains an inner string of 9⅝ inch casing through which gas is flowing at a rate in the order **30** million cubic feet per day from a reservoir at a depth in the order of **20** thousand feet, the total weight of lead balls required to cause compaction and flow shut-off is apt to be in the range of from one-fourth to two-thirds of the weight of a full fluidized bed within the 9⅝ inch casing.

Where desired, the steps of injecting dense large balls can be by-passed by inserting enough tubing into the wild well to restrict the outflow of fluid to one that can be confined by an injection of a relatively dense fluid, such as mud or cement.

What is claimed is:

1. A process for confining a flow of relatively low density fluid from a wild well from which such a fluid is outflowing, comprising:

extending a fluid-confining conduit from a surface location to a selected intermediate depth within the well;

initially inflowing fluid having a density exceeding that of the outflowing fluid by pumping it through said conduit and into the well;

adjusting the depth of said selected location and the amount and density of said inflowed fluid so that, at the selected depth, the effective particle lifting

energy of the outflowing fluid is insufficient to lift a relatively large dense particle having a density and shape that causes it to fall relatively rapidly through a fluid of relatively low density;

entraining relatively large dense particles having said density and shape in said inflowing fluid so that they are transported into the borehole of the wild well to form a relatively low permeability bed of particles that impedes the flow of the outflowing fluid; and

subsequently, inflowing sufficient relatively high density fluid material to substantially terminate the outflowing of fluid from the well.

2. The process of claim **1** in which said relatively large dense particles consist essentially of particles substantially equivalent to lead balls having a diameter of at least about one-eighth inch each.

3. The process of claim **1** in which said extending of a fluid-confining conduit is conducted by inserting a string of tubing into the borehole of said wild well.

4. The process of claim **1** in which said initially inflowed relatively high density fluid is drilling mud.

5. The process of claim **1** in which said subsequently inflowed high density fluid material that is inflowed after the injection of said relatively large dense particles is cement.

6. A system for entering a blowing well from which there is an outflow of fluid, comprising:

remotely controllable movable boom means for supporting and positioning a guide tube means to have one end aligned generally horizontally while the other is aligned with the borehole of the well;

fluid circulating means connected to said boom means for circulating cooling fluid along the boom;

tubing spool means containing spoolable tubing adapted to pass through the guide means and extend into the borehole of the well to a depth at which the lifting energy of the outflowing fluid is significantly less than it is near the surface of the earth;

remotely controllable tubing manipulating means for advancing and retrieving the tubing between the spool means and the well borehole; and

pumping means connected to the tubing and the spool means for pumping fluid through the tubing and into the well.

7. The system of claim **6** in which said guide tube means contains blowout preventer means for controlling any backflow of fluid that might occur.

8. The system of claim **6** in which means for injecting relatively large solid particles is connected to inject particles into said spoolable tubing.

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