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(54) Title: APPARATUS AND METHOD FOR WATER WELL CLEANING AND REHABILITATION

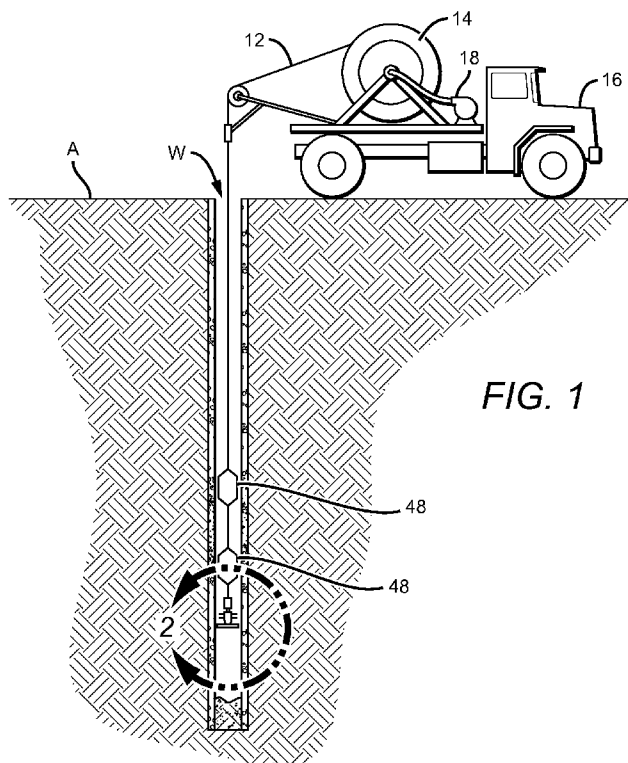


FIG. 1

(57) Abstract: A method and apparatus for cleaning a down hole well is presented. The apparatus utilizes a tool body having a plurality of discharge nozzles for jetting streams of filtered water at pressures exceeding 15,000 psi (1034 Bar) perpendicular on to the inside wall surface of a casing across a zone of interest having slots or perforations. The nozzle streams are offset from the tool body imparting a rotational force. A rotary coupling is also utilized to limit the maximum rotation. The apparatus is lowered by a pre-determined length of coiled tubing to operational depth after which it is raised at a slow rate across the zone of interest.



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APPARATUS AND METHOD FOR WATER WELL CLEANING AND REHABILITATION

CROSS REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of United States utility patent application bearing
5 serial number 13/404,525 filed February 24, 2012 and United States provisional patent
application bearing serial number 61/494,489 filed June 8, 2011, the contents of which is
hereby incorporated by reference herein in its entirety for all purposes.

FIELD OF INVENTION

This invention relates to an apparatus and method for cleaning and rehabilitating
10 down hole wells, particularly water wells.

BACKGROUND OF THE INVENTION

Water wells are created by drilling from the surface of the earth down into a water
producing zone(s). The drilled hole is cased with a suitable string of steel or PVC casing
15 from surface down through the water zone. Typical installations can have the diameter of the
casing through the water zone be from six to sixteen inches or more. The portion of the
casing adjacent the water zone is typically perforated with holes or machine slots to allow
water entry into the casing. After the casing has been set and depending upon the water zone
strata, a clean porous zone of gravel can be pumped and set around the slotted or perforated
20 section of the casing, also referred to as the gravel packed area, out to the lining of the well
bore. The purpose of the gravel pack is to filter out the fine sediment from the surrounding
formation, while allowing the water to enter into and through the perforated well casing.

After a period of time, and due to a variety of different reasons, the slotted or
perforated well casing, and possibly the gravel pack can become plugged with material such
25 as calcium carbonate, iron bacteria, etc. An early indication of plugging is a deterioration of
specific output capacity of the well. Well rehabilitation companies and well owners alike
quantify this deterioration by measuring the amount of drawdown reported in units of gallons
per foot of drawdown (gpm/ft or liters per minute per meter) over a period of time. As
drawdown deteriorates over time, the decision is made to rehabilitate the well using any of
30 various methods well known in the prior art. These methods include acid washes,
reperforating the portion of the casing across the water zone and scrapers to scrape scale

build-up about the inner wall circumference of the casing. Methods also include utilizing a low pressure jet spray which washes the plugging material with water or water in combination with an acid.

One example of prior art well cleaning with a jet spray is disclosed in US Pat. No. 5,060,725 issued to Buell. Buell teaches the use of sufficient hydraulic horsepower to supply a plurality of jet nozzles with at least 0.77 barrels per minute (92 Liters per minute) per jet nozzle to clean perforation tunnels in a well casing or liner.

Although perhaps suitable for oil well cleaning, with respect to water well cleaning the quantity of fluid being introduced by Buell down hole is not recommended or commercially used today. The reasoning is that introduction of such a great volume of water could potentially include unintended contaminants as well as the volume of the wash disrupting the integrity of the gravel pack.

Another example of prior art well cleaning is disclosed in US Pat. No. 5,060,725 issued to Alford. Alford teaches a well cleaning tool comprising a jetting tool used in combination with a surge block. This reference, in respect to use of the jet nozzles, teaches away from cleaning gravel pack screens directly and instead uses the radially orientated jet nozzles to turbulently clean the inside wall of a casing.

US Patent Application Publication US 2012/0018163 by Nelson claims a process for cleaning but having a plurality of nozzles which use a 25 degree (0.44 radian) spray pattern. Such a spray pattern is a turbulent cleaning method that is limited in performance to the inside walls of casing and has negligible cleaning beyond the wellbore. Nelson further claims the use of running his invention "up and down" over a specified depth in order for the invention to perform as outlined. Utilizing needle like cohesive streams (And more than likely fan jet-turbulent streams) of water above 10,000 psi (690 Bar) in this manner will erode and/or actually cut into water well casing by incorporating the suspended abrasive material into the cohesive streams and re-jetting them into the casing.

SUMMARY OF THE INVENTION

My invention is an apparatus and method for cleaning and rehabilitating water wells which avoids the use of harmful chemicals or abrasives and instead, uses low water volume but in a high pressure laminar discharge to blast scale and other deposits. As used in this

specification, the term “rehabilitating” means to open perforations through the wall of the water well casing, break up mineralized, bacterial, or other blockages present which may also be encrusting the filter or gravel pack and removing remnant drilling mud from well.

5 The tool of the present invention is used primarily when it is determined that there is a need to clean and open apertures which, over time, have become partially or fully closed as a result of bacteria or incrustations which are untreatable using less time consuming or less invasive methods. Because no chemicals or abrasive material are used, the environmental quality of water produced subsequent to well rehabilitation is not negatively impacted.

10 As is well known in the art, down hole wells may contain perforations, slots, or screens. As is used in this specification, the term “perforation” is defined to include any hole, screen or other conduit for flow of water from the at-depth strata entering into a well casing.

The term “about” as used in this specification is defined to mean plus or minus 5 percent of the value specified.

15 Typically, the wells intended for use with my invention are wells where a final attempt is made to improve production rate before either acquiescing and accepting the low production or where the well may be abandoned and replaced by drilling a new well.

20 The high pressure discharge, at a relative low flow rate through each nozzle, delivers a needle like cohesive water jet stream with sufficient energy to not only clean the casing wall of build-up but also impart a cleaning force through the perforations and into the gravel pack. Prior art cleaning methods, such as the Nelson reference discussed earlier, utilize nozzles having a dispersion pattern such as 25 degrees (0.44 radian). With this type of dispersion, a wider area is sprayed and as a consequence, energy is dissipated over this wider area. By contrast, my invention discourages a dispersion pattern. The stream exiting the discharge nozzles is to be as narrow or focused as practicable. The longer the distance the discharge can be maintained in laminar flow, the more focused the energy resulting from the discharge will be on the well casing surface, perforations, gravel pack, etc. Thus, as used in this specification, laminar discharge means a focused stream of fluid where dispersion of the flow pattern is minimized for as long a distance as practicable. Maintaining a minimal dispersion pattern focuses the cleaning energy of the fluid on a small area of the well casing.

30 Because the well casing will most likely have a water level above the perforations,

this column of water and the pressure it exerts at the depth of the perforations is detrimental to nozzle discharge integrity. Nozzle discharge at lower pressures described as in the prior art (i.e. <10,000 psi; < 690 Bar) will disperse easier under the water column pressure and result in a lower energy stream of water for cleaning the inside casing wall. It is for this reason that a laminar discharge is necessary and will be less affected by the pressure caused by a high water column.

My method comprises the use of a down hole tool which is lowered into a water well preferably using a pre-determined length of coiled tubing such as either stainless steel coiled tubing or a wire-reinforced thermoplastic impregnated hose. The pre-determined length must be sufficient to lower the tool to the necessary depth. The down hole tool is appropriately sized to pass through the inside diameter of the lowermost casing string.

The conduit used must be capable of withstanding a high pressure application of over 15,000 psi (1034 Bar). The tubing or hose used will have an appropriate inside diameter for the depth of the well to be cleaned. Preferably, the inside diameter used for wells less than 1000 ft (305 m) in depth is at least 20 mm and for wells in excess of 1000 ft (305 m), at least 24 mm; or, an inside diameter which is capable of discharging water at the necessary well depth from a plurality of discharge nozzles orientated so that each discharge stream will impact the casing wall or extend through perforations and to the gravel pack or outer strata at about 90 degrees at pressures exceeding 15,000 psi (1034 Bar).

It has been determined the pressure at the discharge of each nozzle should be at least 15,000 psi (1034 Bar) in order to effectively penetrate perforated casing and surrounding gravel pack. The flow rate passing through each nozzle is limited to between about 5.0-7.0 gpm (19.0 – 26.5 Liters per minute). My invention is not applicable at down hole discharge pressures of less than 15,000 psi (1034 Bar). It is the energy communicated by the laminar needle-like discharge at high pressure, which provides the necessary cleaning effect to dislodge scale and other buildup which exists in the casing and outer wellbore.

The down hole tool is supported from the coiled tubing/hose using an appropriate length of rigid pipe equipped with centralizers for providing stability.

Below the rigid pipe section is a rotary coupling to retard excessive rotation. Although various rotary couplings are known in the art to control rotation, including mechanical, preferably a rotary coupling is selected which utilizes braking fluid to retard

excessive rotation similar to that known in the prior art and described in US Pat. No. 6,059,202. The purpose of the rotary coupling is to provide a control means for limiting the rotation of the discharge nozzles to an acceptable rate, which for the purposes of my invention, is between about 20-50 rpm.

5 The rotary coupling has an intake orifice, an inside diameter flow path equivalent to the intake orifice of the down hole tool and an exit orifice and is operatively attached to the down hole tool. Preferably, attached downstream of the rotary coupling is a neck which serves as a connector between the rotary coupling and down hole tool.

10 At this point, it should be noted that because of the down hole pressure and flowrate required for proper operation of my invention, friction loss of the water traveling through the system must be kept at a minimum. Accordingly, the flow path from the discharge of the surface pump, to the down hole tool should be designed to minimize friction loss as is practicable.

15 The down hole tool operatively connected to the rotary coupling comprises a tool body having an inside diameter which is about the same as the coiled tubing and rotary coupling above to minimize friction loss and turbulence. Thus, the flow path from the pump to the tool body is designed to minimize turbulence and not only promote laminar flow but also to minimize pressure drop between the pump and the discharge nozzles.

20 The tool body has an intake orifice and serves to separate the pumped water into separate streams through a plurality of exit ports which feed through discharge nozzles as will be shortly described. Although the tool body design is configured so that the discharge nozzles attach directly to the tool body, such a design would be impracticable for use in water wells having significantly different diameters, because of the proximity required between discharge nozzle and casing wall surface. Thus, in environments where only a single size of casing diameter will be encountered, the tool body can be designed so that the discharge
25 nozzles are either directly connected to the tool body or operatively connected to the tool body by the use of elongated pipes which are appropriately sized so that the nozzle tip is located between 0.5 and 2.5 inches (12.7 and 63.5 mm) from the inside wall of the casing. Since water wells of various diameters exist, it is more practicable to design a smaller
30 diameter tool body which can be used in most water wells and then configure the tool body

with appropriately sized elongated nozzle pipes, the lengths of which can be optimized for the particular diameter of the well to be rehabilitated.

In the preferred embodiment, the tool body comprises a plurality of perpendicular exit ports each connecting to a respective nozzle pipe having a distal end fitted with a discharge nozzle. Each connection provides a water tight connection able to withstand at least 15,000 psi (1034 Bar) which embodies a straight, fine thread connection with either an “O” Ring or metal to metal seal. Again, because of the high pressures required for my well rehabilitation method, National Pipe Thread (NPT), although acceptable for low pressure cleaning methods of the prior art (<10,000 psi) (< 690 Bar), NPT is not recommended for my high pressure use.

Preferably, the nozzles are offset and orientated in a perpendicular or nearly perpendicular direction away from the tool body for facing the inside wall of a casing to be jetted with a high pressure laminar discharge. Each nozzle is thus orientated in a direction perpendicular to the central axis of the primary tool body. Most preferably, the offset is between about 0.23 inches (5.842 mm) and 0.27 (6.858 mm) inches off the center line of the tool body. Because the nozzle pipes are offset, flow through the discharge nozzles will cause the tool body to rotate. Preferably, the number of nozzle pipes are an even number; such as six, eight or ten. Most preferably, orientation of the discharge nozzles is arranged so that each nozzle has a unique vertical position. Stated differently, if the tool body is at depth in a well and not being displaced, each nozzle would face the casing wall at a different height. This difference in vertical orientation relative to each other nozzle creates a cleaning pattern which covers substantially all of the inside casing wall surface as the tool is raised between 1-2.5 fpm (0.31 – 0.76 mpm) while rotating between 20-50 rpm.

In one preferred embodiment of my invention, an even plurality of at least four offset nozzles are arranged so that each nozzle has its own respective height on the tool body configuration. For a set of four offset nozzles, one embodiment can be that each nozzle is at 90 degrees from the nozzle immediately above or below and in a direction perpendicular to the central axis of the primary tool. For a set of six offset nozzles, one embodiment can be that the first four nozzles are as described above for the four nozzle set and the fifth and sixth nozzles are 180 degrees from each other and 90 degrees from the orientation of the fourth nozzle in a direction perpendicular to the central axis of the primary tool. For a set of eight offset nozzles, the pattern could be a repeat of the four nozzle set. Likewise, for a set of ten

nozzles, the pattern could be a repeat of the four nozzle set with the ninth and tenth nozzles are 180 degrees from each other and 90 degrees from the orientation of the eighth nozzle in a direction perpendicular to the central axis of the primary tool. The same methodology could be utilized for orientation of a larger plurality of offset nozzles.

5 It is further important to note that my invention incorporates the retraction of the tool in one motion, making one complete travel in the vertical motion due to concerns of damage created by running multiple passes. The material dislodged will create an environment of free floating abrasive material that will be incorporated into the jetting pattern if ran back and forth (up and down or multiple concurrent passes of the tool), thereby creating a cutting or
10 erosion effect into the casing. The design and operation of this invention alleviates this outcome.

 The distance of each discharge nozzle away from the center line of the tool body is dependent upon the inside diameter of the well to be worked upon. Thus, after the inside diameter for the specific well to be jetted has been identified, the correct length of nozzle
15 pipe is selected and thereafter attached to the tool body. The nozzle pipe length is selected so that the discharge nozzles, attached to the distal end of each nozzle pipe, are located between about 0.5-2.5 inches (12.7 mm – 63.5 mm) from the inside face of the casing at the known depth range of the perforations.

 In order to prevent the discharge nozzles and nozzle pipes from contacting the casing
20 wall, in addition to the centralizers positioned above the rotary coupling, there is also a protective disc located beneath the tool body. The protective disc has a diameter which is about 0.5 inches (12.7 mm) less than the inside diameter of the casing at-depth and has a radius which is about 0.25 inches (6.35 mm) greater than the radial extent of each discharge nozzle. Therefore, the nozzles and nozzle pipes will not come in direct contact with the
25 casing wall which could cause damage to the nozzle array.

 Besides flow rate and pressure mentioned earlier, equally important is the characteristic of the exiting flow from each discharge nozzle. Specifically, the needle like cohesiveness of the flow from each nozzle, i.e. a laminar flow is desired to be maintained for as long a discharge distance as practical. It has been determined that fluid character upstream
30 of the nozzle is a critical variable which is determinative of the fluid character discharged and the conditions for causing turbulent flow should be kept at a minimum.

Because of the high pressure required, most fittings are preferably metal-to-metal autoclave fittings further utilizing O-rings to not only prevent leakage at the joints but also reduce friction loss across joint interfaces. Combined with the use of coiled tubing, friction loss is minimized as the water is pumped from surface and exiting the discharge nozzles.

5 One additional concern addressed by my invention is the prevention of excessive and detrimental erosion which tends to occur at the discharge nozzle holder immediately and axially about the flow path. Because any expansion of the nozzle holder opening caused by erosion will invariably erode or destroy the diamond or sapphire orifice, thereby reduce the discharge pressure, it is critical that the discharge nozzle holder be constructed of material
10 resistant to erosion. In a preferred embodiment, the discharge nozzles incorporate a press-fit funnel constructed from either commercial grade sapphires or diamonds with a diameter of about 0.040 inches (1.02 mm). The material of construction and flow path created are critical in maintaining the needle like cohesive flow of the existing water jets. Also, a press-fit cylindrical erosion insert preferably made from heat treated 400 series stainless steel is
15 positioned on the discharge side.

With the make-up of the tubing string described, my method of use will now be described.

Filtered well water is preferably used as the cleaning fluid. This reduces the risk of contaminants being introduced into the well during the cleaning operation. Abrasives are not
20 contemplated to be used as part of my invention and the preferred embodiment of my invention has the cleaning fluid consisting of filtered well water. Abrasive material could plug or destroy the precision cut orifices. Thus, my invention opens the down hole perforations using the force of a high pressure, substantially needle like laminar flow stream.

At surface, a vehicle is moved into position as illustrated in Fig. 1. The tool body,
25 nozzle pipes, neck, rotary coupling, rigid tubing, stabilizers and distal end of the coiled tubing are operatively connected together and after being pressure tested, the tool body is lowered into the well until the discharge nozzles are adjacent to and facing the lowermost casing wall to be cleaned. Once at depth, a surface pump, operatively connected to the plurality of perpendicular discharge nozzles, is activated to pump filtered well water at a sufficient
30 volume. The volume is dependent upon the number of discharge nozzles being used. With the desired flow rate being between about 5-7 gpm (19 – 26.5 lpm), the flow rate using a tool

body equipped with 6 discharge nozzles would be between about 30-42 gpm (114 – 160 lpm); for 8 nozzles, 40-56 gpm (151 – 212 lpm); and for 10 nozzles, 50-70 gpm (190 – 265 lpm). This flow rate through the offset discharge nozzles will cause the tool body to rotate. Because of the high pressure flow being generated an appropriately designed rotary coupling, preferably utilizing high viscosity breaking fluid, is operably connected to the tool body to limit the rate of rotation to between about 20-50 rpm.

During the pumping operation, the coiled hose/tubing is slowly retracted, between about 1-3 feet per minute (0.31 to 0.91 meters per minute) across the perforated water zone. This retraction rate in tandem with the nozzle body rotation rate, limits the time a specific area of the casing wall is exposed to the high pressure fluid stream exiting from each discharge nozzle. The exposure time is sufficient to blast off any scale, rust or other fouling material which is present as well as allowing time for the fluid stream to penetrate past the perforations and into the formation consisting of the gravel or filter pack and affected remnant mud on the well bore. However, the exposure time is not so prolonged to cause damage to the casing; provided the casing is in good condition. The combination of tool body rotation, slow tool retraction and high pressure laminar output from the plurality of perpendicular discharge nozzles results in all or nearly all of the inside casing wall coming in contact with the high pressure fluid discharge.

As stated earlier, the desired position of the discharge nozzles from the casing wall is between about 0.5 and 2.5 inches (12.7 and 63.5 mm). Distances further than 2.5 inches (63.5 mm) would cause the integrity of the exiting stream to progressively deteriorate enough to not affect the zones beyond the filter pack and onto the well bore. Some well conditions may exist where it may not be possible to position the discharge nozzles within this range due to excessive scale or rust build-up. In these situations, it may be necessary to first run a scraper down hole and possibly run the tool body with a smaller set of nozzle pipes and protector disc as an initial cleaning run.

Following the jetting run, the pump is turned off and the tool body is retrieved. The result is that the scale, rust and other fouling material present has been blasted off the casing wall and the perforations have been opened. For optimum water production, subsequent to the jetting run, a surge tool should be run down hole for displacing any of the blasted material which may have entered the strata by passing through a perforation during blasting. Following use of a surge tool, the blasted off material, now located at the bottom of the well,

should be removed by any technique known in the art such as air-lift, foam nitrogen or by bailing.

My method for opening the perforations of a well having a known casing inside diameter at depth comprises the steps of:

- 5 providing a water source and a pump capable of pumping between about 30-70 gpm (114 – 265 lpm) at a pressure in excess of 15,000 psi (1034 Bar);
 providing a retractable flow path from said pump to the downhole perforations; and,

 a means to deliver an even plurality of perpendicular high pressure laminar discharge streams onto the inside casing wall at a rate of between about 5-7 gpm (19 – 26.5 lpm) at a
10 pressure in excess of 15,000 psi (1034 Bar) while the rotation of said discharge streams is limited to between about 20-50 rpm. The retractable flow path comprises the string of tubing, the rotary coupling and down hole tool. The means to deliver the even plurality of discharge streams addresses the specific characteristics of both the rotary coupling and down hole tool which have been described earlier in this specification.

15 My apparatus is primarily focused to rehabilitate production wells suffering from encrustations, scale and other mineral deposits which are detrimentally affecting well production performance. Because of the high pressures involved in utilizing my apparatus and the relatively small orifice size for each nozzle (about 0.040 inch; 1.02 mm), the service life of each nozzle is limited and must be evaluated/replaced after each use.

20 The focused, needle-like laminar discharge is capable of transmitting sufficient energy to dislodge encrustations existing not only on the adjacent well casing but also capable of transmitting the energy through perforations to dislodge mineral deposits and drilling mud. It has been discovered if the laminar flow is not focused on a particular casing portion for a prolonged period of time, no casing damage will occur unless the casing has
25 already been severely compromised by corrosion.

DESCRIPTION OF THE DRAWINGS

Fig. 1 is a side view representation of the tool positioned at depth.

Fig. 2 is a view of Fig. 1 about circle 2 of Fig. 1.

Fig. 3 is a perspective view of my primary tool.

30 Fig. 4 is a top view illustrating the offset nozzle pipes taken along line 4-4 of Fig. 3.

Fig. 5 is a cut away view of the nozzle pipe and discharge nozzle.

Fig. 6a is a side view of the discharge nozzle.

Fig. 6b is a face view of the discharge nozzle.

Fig. 6c is a cut away view of the discharge nozzle taken along line 6c-6c of Fig. 6a.

5 BEST MODE FOR CARRYING OUT THE INVENTION

The drawings presented are not to scale and are presented for instructional purposes.

Fig. 1 illustrates an overall view of the invention for delivery of high pressure streams of fluid into well W.

Primary tool 10 is lowered into well W down to the target depth by stainless steel
10 coiled tubing 12 from a hydraulically driven reel 14 installed on a service vehicle 16 above surface A. Tubing 12 must be capable of withstanding a flow pressure of at least 15,000 psi (1034 Bar). As can be best viewed in Figs. 2 and 4, primary tool 10 is lowered to the portion of the well, which in this example is adjacent to slot perforations represented by the dashed line S, surrounded by gravel pack G.

15 The distal end of tubing 12 is operably connected to primary tool 10 as described later in detail. When reel 14 is used to unwind tubing 12 to lower primary tool 10 to the target depth, i.e. the lowermost portion of the well to be cleaned, which generally can be at a depth anywhere from 20 (6.1 m) to 3,000 feet (915 m), the pumping system is thereafter activated using a 500 HP (373 Kw) diesel driven high pressure pump 18. The feed water used to
20 produce the high pressure nozzle discharge is local well water so as to not introduce contaminants into the well. The feed water is supplied at a rate of between 30 to 70 gallons per minute (gpm) (114 to 265 Liters per minute (lpm)) at approximately 40 pounds per square inch (2.76 Bar) through a filtration system (not shown) located upstream of pump 18.

Primary tool 10 comprises several components and is best illustrated by Fig. 2 and
25 Fig. 3. A high pressure, high torque, low rpm, viscous braking rotary coupling 20 having a combination of high pressure seals and metal to metal rotary seals prevent feed water leakage. Rotary coupling 20 can be model 20k BJV™-20K manufactured by Stoneage Waterblast Tools, Durango, Colorado, US. Below rotary coupling 20 is operably connected to a down hole tool comprising a tool body 22 having connected thereto a plurality of offset
30 nozzle pipes 24 each having a distal discharge nozzle 36. The offset is best illustrated in Fig.

4 and is 0.25 inches (6.35 mm) off the center line of the tool body. The torque necessary for rotation of rotary coupling 20 is generated by the discharge exiting each nozzle 36. Nozzle pipes 24 extend away from tool body 22 in a perpendicular direction and face the inside wall of the well casing. Tool body 22 incorporates a bleeder port 52 for each nozzle.

5 As best illustrated in Fig. 5, each nozzle pipe 24 has a fluid entry 10 to 20 degree (0.17 to 0.35 radian) tapered inlet 30, an O-ring 32, threads 34, and distal nozzle 36. A conduit 38 connects inlet 30 to nozzle 36.

Fig. 6a is a side view of nozzle 36 and comprises a threaded stem 40 and a head 42. Fig. 6b is a top view of nozzle 36 illustrating head 42 and a cylindrical shaped tungsten carbide erosion protective insert 44 which press-fit into nozzle 36. Insert 44 is used to
10 withstand the erosion forces generated, particularly resulting from the flow and turbulence immediately following jet contact with the casing wall. The inside diameter of insert 44 is about 0.142 inches (3.61 mm). Also present is a precision cut cone 50 for funneling the flow from conduit 38 down to an exit orifice having a diameter of about 0.040 inch (1.02 mm) and
15 made from either a commercial grade diamond or sapphire to develop a needle like cohesive laminar discharge jet of at least 15,000 psi (1034 Bar). Nozzle 36 is made from stainless steel. Fig. 6c is a cut away view of nozzle 36 taken along line 6c-6c of Fig. 6a and illustrates the flow path for water.

The plurality of nozzle pipes 24 are offset in relation to tool body 22 in such a manner
20 that the fluid discharge exiting nozzles 36 create a force to rotate tool body 22. Rotary coupling 20 incorporates a silicon based non-hazardous breaking fluid (not shown) and effectively maintains a steady rotating speed of between about 20 to 50 rpm when a flow rate of between about 30-70 gpm (114 – 265 lpm) is maintained.

The vertical height of the cutting pattern is approx. 2" (50.8 mm) (using tool body 22
25 with six nozzle pipes 24) to 4" (101.6 mm) (using tool body 22 with ten nozzle pipes 24).

For different diameter wells, a respective length of nozzle pipe 24 is selected so that nozzle 36 is located between about 0.5 (12.7 mm) to about 2.5" (63.5 mm) from the inner wall of the perforated casing wall.

A protective disc 46 is located beneath tool body 22 to protect the nozzle pipes 24
30 from being crushed against the inner wall of the casing. Protective disc 46 is appropriately sized to allow for travel within a casing string while having a radius which is longer than

each nozzle pipe 24. The diameter of protective disc 46 is slightly larger than the extent of nozzle pipe 24 from tool body 22 as shown in Fig. 8. Protective disc 46 ensures that nozzles 36 do not come in direct contact with the casing wall yet permits discharge nozzles 36 to come to within about 0.5 (12.7 mm) to about 2.5 inches (63.5 mm).

5 In order to maintain a minimum friction loss and to promote a needle like laminar flow stream exiting from each discharge nozzle, each exit port on the tool body, which has an inside diameter of about 0.303 inches (7.7 mm), flows into the proximal end of a nozzle pipe 24 having an inlet taper of about $13\pm 2^\circ$ (0.23 +or- 0.035 radian) until the inside diameter of the nozzle tube is reached, preferably about 0.19 inches (4.83 mm). The inside diameter of
10 conduit 38 remains constant up to contact with discharge nozzle 36 located at the distal end. Each discharge nozzle 36 has a tapered configuration as best illustrated in Fig. 6c prior to fluid discharge.

Each nozzle pipe 24 is threadably secured to tool body 22 using straight threads to engage a metal to metal seal and sealed using "O" rings 32.

15 Tool body 22 is a compact component. For a 6 nozzle configuration, the vertical distance between the highest and lowest nozzle is about 2.25 inches (57.15 mm); for an eight nozzle configuration, about 2.625 inches (66.675 mm); and, for a 10 nozzle configuration, about 3.00 inches (76.2 mm).

By minimizing the spacing of the jet pattern and pulling primary tool 10 to surface at
20 a steady rate of about 1.0 to 2.5 feet per minute (0.31 to 0.76 meters per minute), the jet streams generated by the nozzle discharge effectively open the perforations of the casing as well as into the formation comprised of the filter or gravel pack and onto the original well bore. The fluid stream exiting from discharge nozzle 36 is at such a high pressure and needle like cohesion that the stream can extend through the perforations to break up pluggage also
25 found incrusting the gravel pack and mud cake left over on the well bore from the original drilling. The possibility of damage to the casing is remote due to the relatively high rotational speed and slow vertical displacement of primary tool 10. Coupled with the fact that clean filtered well water is used, no abrasive is introduced that would facilitate hydro cutting of material that is far stronger than the energy used to open the perforations and
30 reinvigorate the gravel pack.

Centering of primary tool 10 down hole is accomplished by employing a plurality of

six aluminum or EPDM Centralizers 48 that are 24" (610 mm) long positioned above rotary coupling 20 and attached to a pre-determined length of rigid tubing 26, typically between 4-10 feet (122 to 305 cm). This length is determined on-site which will be necessary to provide adequate centering of rotary coupling 20 and tool body 22 within the well casing. Rigid tubing 26 is connected upstream to coiled tubing 12 and downstream to rotary coupling 20. The flow path through coiled tubing 12, rigid tubing 26, rotary coupling 20 and tool body 22 minimizes friction loss during the pumping operation. Each centralizer 48 is appropriately selected for use in a well having a particular inside diameter in the same manner as is the length of nozzle pipes 24. As is well known in the art, the tool sizes have to take into account the down hole condition inside the casing including the buildup of fouling material to be encountered in the inside diameter of the casing and perforated casing walls.

Once primary tool 10 has been lowered to the starting depth, which is adjacent to the deepest perforations across the water zone, and the pumping process has been initiated, the operator adjusts the driven reel to reflect the rate of retrieval speed by timing the reel with an onboard stop watch gauged against a depth counter (not shown) affixed to the tubular conveyance on the surface until the proper speed is attained. The pump is then throttled up to the desired pressure range of preferably between 15,000 psi - 21,000 psi (1034 bar – 1450 Bar) and the tool is retrieved at the rate of 1.0-2.5 fpm (0.31 to 0.76 meters per minute).

The connection used for the interfaces between the primary tool and the coiled tubing is a high pressure beveled, metal to metal seal. Pipe threaded connections (NPT) are not recommended because of their unreliability and safe use above 14,500 psi (1000 Bar). Therefore, all connections subjected to such high pressure, as well as the hose or tubular equipment used, must be designed to withstand extreme high pressure as outlined by International Standards and General Engineering specifications.

The process is capable of reaching depths of 3000 feet (915 meters) using 24 mm coiled tubing. The depth for which my invention can be used is limited only by the currently available coiled tubing maximum diameter. 20mm inside diameter coiled tubing can be used for shallow wells. However, with the flow rates and pressures used, backpressure created by frictional loss is a major concern, and for depths between 1000 feet (305 meters) to 3000 feet (915 meters), the inside diameter is preferred to be 24mm.

When the tool has reached the upper limit of perforated casing, the pump is shut down and the tool is retracted from the well.

1 Claim 1. An apparatus for cleaning the inside wall of a well casing having
2 perforations across a known depth range and the well casing further having a known inner
3 diameter, the apparatus comprising:

4 a primary tool comprising a rotary coupling, a rotatable tool body operably connected
5 to and located beneath said rotary coupling, said tool body having an even plurality of at least
6 four offset nozzles, each nozzle located at a different vertical height from the other nozzles
7 and orientated in a direction perpendicular to the central axis of the primary tool, each of said
8 nozzles positioned to be between about 0.5 to 2.5 inches (12.7 to 63.5 mm) from the inside
9 wall, each of said nozzles appropriately sized to deliver a high pressure laminar discharge of
10 at least 15,000 psi (1034 Bar) at a flow rate of between about 5-7 gpm (19 – 26.5 lpm);

11 a driven reel for unwinding and retracting a pre-determined length of coiled tubing
12 having proximal and distal ends, said coiled tubing capable of withstanding an internal
13 pressure of at least 15,000 psi (1034 Bar), said distal end operatively connected to said
14 primary tool and said coiled tubing of sufficient length to lower said primary tool to the
15 known depth; and,

16 a pump connected at its discharge to said proximal end of said coiled tubing, said
17 pump capable of pumping at a pressure of at least 15,000 psi (1034 Bar) and at least 30
18 gallons per minute.

Claim 2. The apparatus of claim 1 where said discharge nozzles each contain a press-fit funnel incorporating a discharge orifice having a diameter of about 0.040 inches (1.02 mm).

Claim 3. The apparatus of claim 2 where said discharge orifice is made from a commercial diamond.

Claim 4. The apparatus of claim 2 where said discharge orifice is made from a commercial sapphire.

Claim 5. The apparatus of claim 1 where said discharge nozzles each contain a cylindrical erosion protective insert press-fit into the discharge side.

Claim 6. The apparatus of claim 5 where said cylindrical erosion protective insert is constructed of heat treated 400 series Stainless Steel.

Claim 7. The apparatus of claim 1 further comprising a protective disc connected to and beneath said tool body, said protective disc having a diameter less than that of the well casing but having a diameter larger than the distance said discharge nozzle is from the center of said tool body.

Claim 8. The apparatus of claim 7 where said protective disc has a diameter about 0.5 inches (12.7 mm) less than the inside diameter of the casing at-depth.

Claim 9. The apparatus of claim 1 where the number of said even plurality of nozzles is six.

Claim 10. The apparatus of claim 1 where the number of said even plurality of perpendicular nozzle pipes is eight.

Claim 11. The apparatus of claim 1 where the number of said even plurality of nozzles is ten.

1 Claim 12. A method for opening the perforations of a well where the well has a
2 known casing inside diameter and a known range of downhole perforations, the method
3 comprising the steps of:

4 providing a water source and a pump capable of pumping between about 30-70 gpm
5 at a pressure in excess of 15,000psi (1034 Bar);

6 providing a tool body having a plurality of discharge nozzles arranged to be offset
7 from the centerline of said tool body, each discharge nozzle appropriately sized to permit a
8 flow rate of between about 5-7 gpm (19 – 26.5 lpm) at a pressure in excess of 15,000 psi
9 (1034 Bar), and a rotary coupling operatively connected above said tool body to limit the
10 rotation of said tool body to between about 20-50 rpm when the flow rate through each said
11 discharge nozzle is between 5-7 gpm (19 – 26.5 lpm);

12 providing a flow path from said pump to said tool body;

13 lowering said tool body and said rotary coupling so said discharge nozzles are
14 adjacent to the lowermost depth of the downhole perforations;

15 pressurizing said coiled tubing to at least 15,000 psi (1034 Bar); and,

16 retracting said primary tool at a rate of between about 1.0-2.5 fpm (0.31 – 0.76 meters
17 per minute) across said known depth range of perforations.

1 Claim 13. An apparatus for delivery of a high pressure water jet for opening the
2 perforated sections and into the formation beyond a well casing having down hole
3 perforations across a known depth range and the well casing further having a known inside
4 diameter, the apparatus comprising:

5 a tool body having an outside diameter adapted to pass through the inside diameter of
6 a well casing, said tool body having an intake orifice and a plurality of exit ports, each of said
7 exit ports offset from the center line of said tool body and further define the intake stream for
8 a respective discharge nozzle, each of said discharge nozzles positioned to face the inside
9 wall of a well casing and further having a unique vertical position on said tool body, each of
10 said discharge nozzles being adapted with a cylindrical erosion protective insert and a conical
11 shaped insert positioned upstream of said erosion protective insert, said conical shaped insert
12 having a discharge end diameter sized for a laminar discharge flow rate through said insert of
13 between about 5-7 gpm (19 – 26.5 lpm) at a pressure of greater than 15,000 psi (1034 Bar);
14 and,

15 a protective disc attached beneath said tool body, said protective disc having an
16 outside diameter adapted to pass through the inside diameter of a well casing but larger than
17 said outside diameter of said tool body.

Claim 14. The apparatus of claim 13 further comprising a rotary coupling having an intake orifice, a discharge orifice, and an inside diameter flow path equivalent to said intake orifice of said tool body and operatively connected to the intake orifice of said tool body, said rotary coupling capable of retarding the rotation of said tool body to between about 20-50 rpm when a flow rate of between about 30-70 gpm (114 – 265 lpm) is passing through said rotary coupling.

Claim 15. The apparatus of claim 14 further comprising a predetermined length of rigid tubing operably connected on one side to the intake orifice of said rotary coupling, said rigid tubing further having at least one centralizer secured about said rigid tubing and having an outside diameter adapted for use in the well casing.

Claim 16. The apparatus of claim 13 further comprising a predetermined length of coiled tubing having proximal and distal ends, said distal end operatively connected to said rigid tubing.

Claim 17. The apparatus of claim 16 further comprising a water source and a pump where said pump is operatively connected to the proximal end of said coiled tubing and is capable of a fluid displacement of between about 30-70 gpm (114 – 265 lpm) at a pressure in excess of 15,000 psi (1034 Bar).

Claim 18. The apparatus of claim 17 where said coiled tubing is attached to a powered reel.

Claim 19. The apparatus of claim 13 where connected to each of said exit ports is a respective nozzle pipe having an inlet taper of about $13 \pm 2^\circ$ ($0.23 +$ or $- 0.035$ Radian) to an

inside diameter of about 0.19 inches (4.83 mm) which is connected to a respective discharge nozzle.

Claim 20. The apparatus of claim 13 where each of said discharge nozzles are positioned no more than 2.5 inches (63.5 mm) from the inner wall face of the casing at the known depth range.

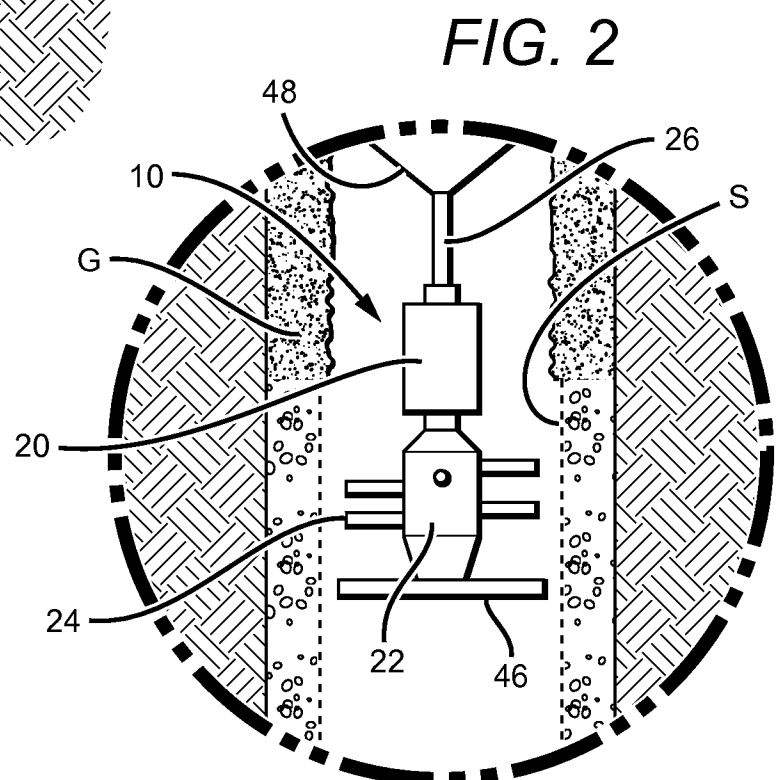
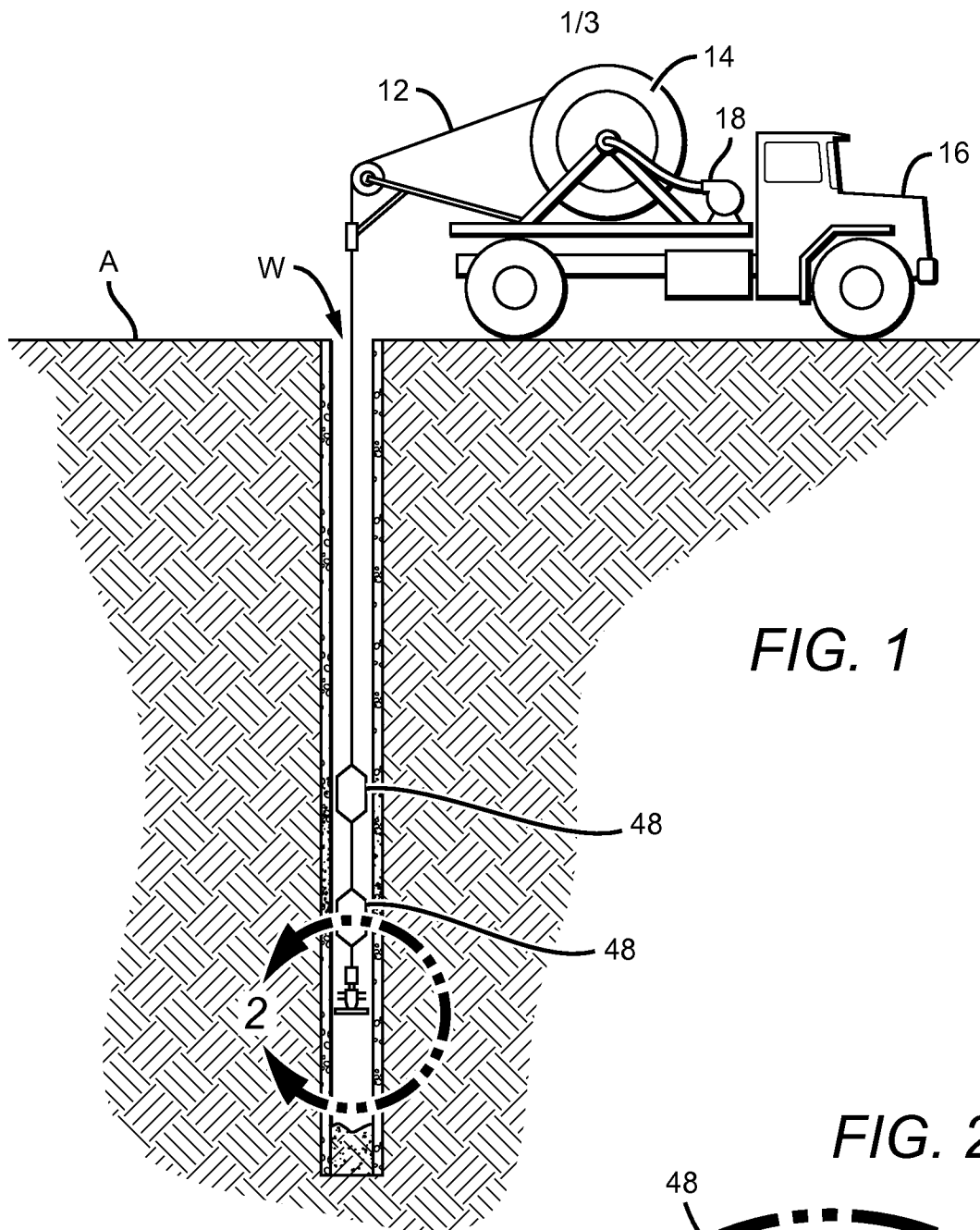
Claim 21. A method for opening the perforations of a well where the well has a known casing inside diameter and a known range of downhole perforations in the casing wall, the method comprising the steps of:

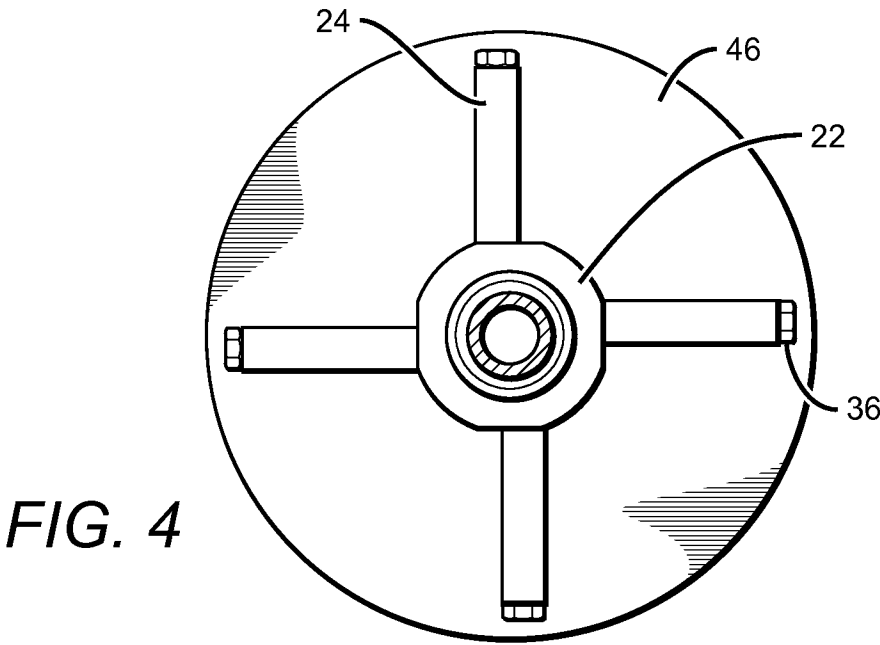
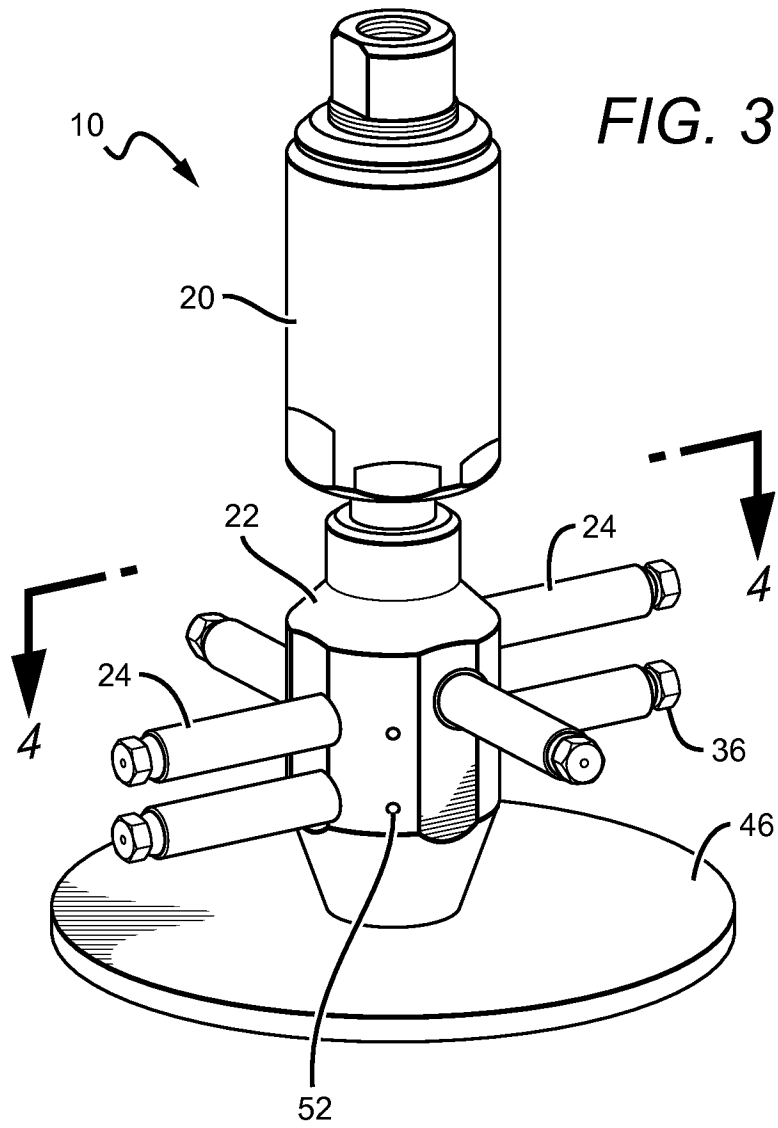
providing a water source and a pump capable of pumping between about 30-70 gpm (114 – 265 lpm) at a pressure in excess of 15,000psi (1034 Bar);

providing a retractable flow path from said pump to the downhole perforations; and,

means to deliver an even plurality of discharge streams onto the inside casing wall at a rate of between about 5-7 gpm (19 – 26.5 lpm) at a pressure in excess of 15,000 psi (1034 Bar) while the rotation of said discharge streams is limited to between about 20-50 rpm.

Claim 22. The method of claim 21 where said retractable flow path comprises coiled tubing attached to a reel, said reel can be retracted at a rate of between 1.0-2.5 fpm (0.31 – 0.76 meters per minute) across said known depth range of perforations.





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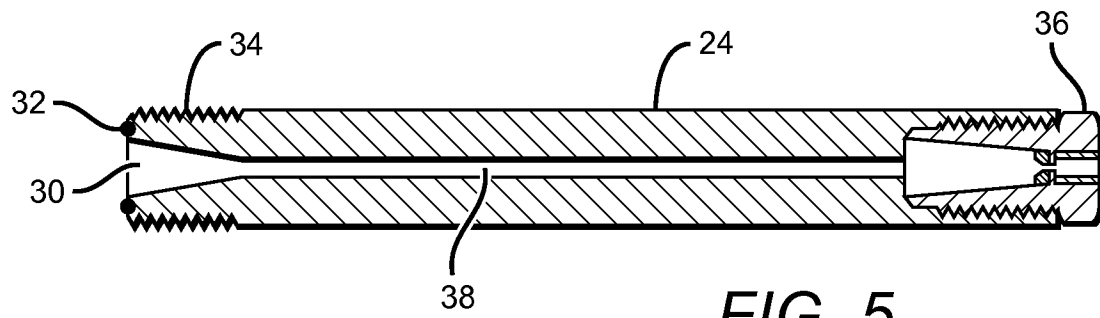


FIG. 5

FIG. 6a

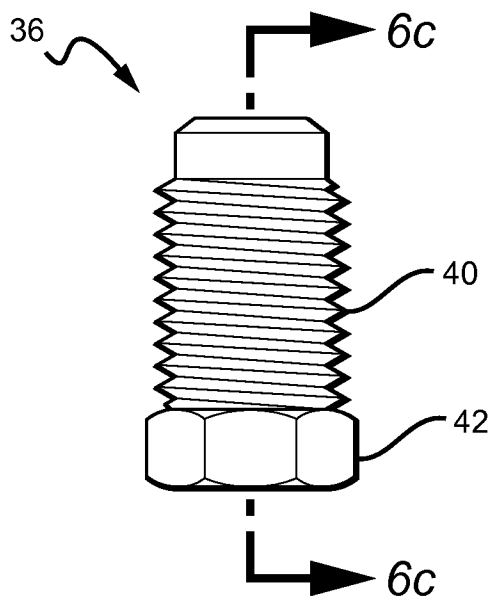


FIG. 6b

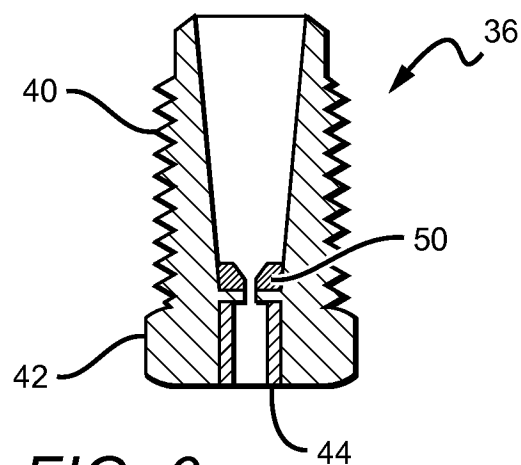
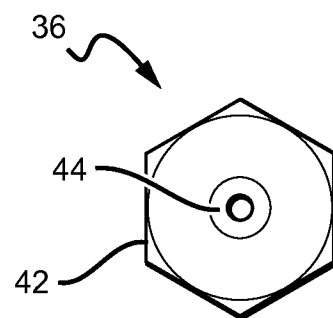


FIG. 6c