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# United States Patent [19]

**Smith et al.**

[11] **3,722,594**

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## [54] WELL METHODS USING SMALL DIAMETER TUBING


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[21] Appl. No.: **145,476**

**Related U.S. Application Data**

[63] Continuation-in-part of Ser. No. 873,932, Nov. 4, 1969, abandoned.

[52] **U.S. Cl.**.....**166/305 R,** 166/279, 166/307, 166/311

[51] **Int. Cl.**....**E21b 21/00,** E21b 43/25, E21b 43/27

[58] **Field of Search**....166/305 R, 315, 314, 311, 77, 166/279, 310, 307; 175/71



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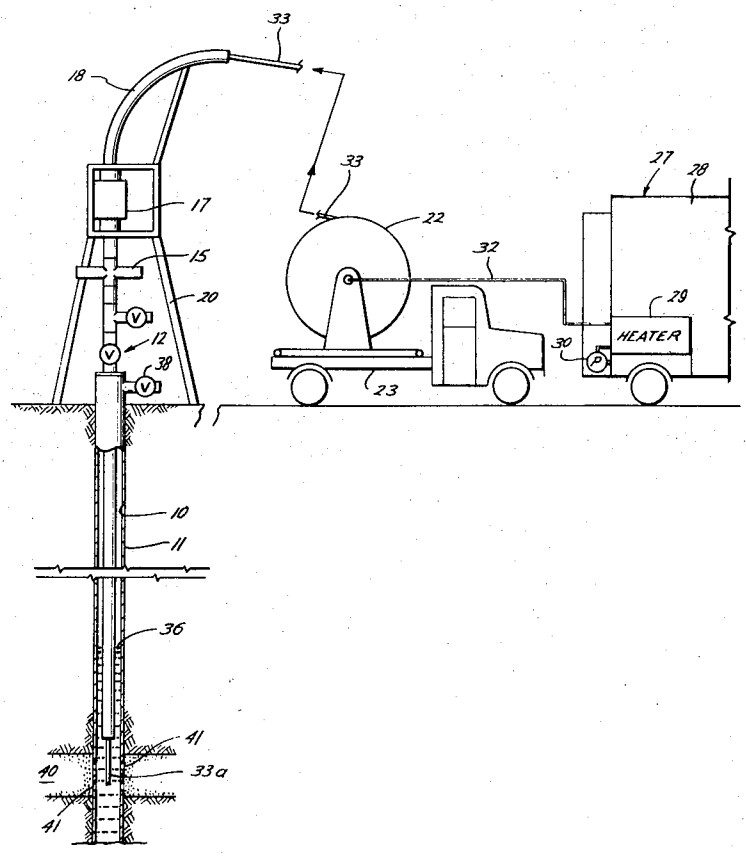
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[57] **ABSTRACT**

Well methods using small diameter tubing introduced into and withdrawn from the well by an injector apparatus. The tubing is introduced into and withdrawn from the well by the injector from a tubing-holding reel. Liquids in the well are removed by gas injection as the tubing is introduced. The methods include displacements, fluid injections such as injections of acids, corrosion inhibitors, surfactants, plastics, cement, drilling fluids, alcohols, other solvents, or other chemicals used for treatments in wells and at formations or reservoirs penetrated by wells. The methods also include methods for the dewatering or drying of pipelines, shafts, ducts, vents, or the like. In most cases, the methods include the introduction of an inert gas such as nitrogen through the small diameter tubing. Other gases may also be introduced through the small diameter tubing. The methods are especially suitable for use in petroleum wells, but may if suitable be used in water wells.


**9 Claims, 5 Drawing Figures**



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2 Sheets-Sheet 1

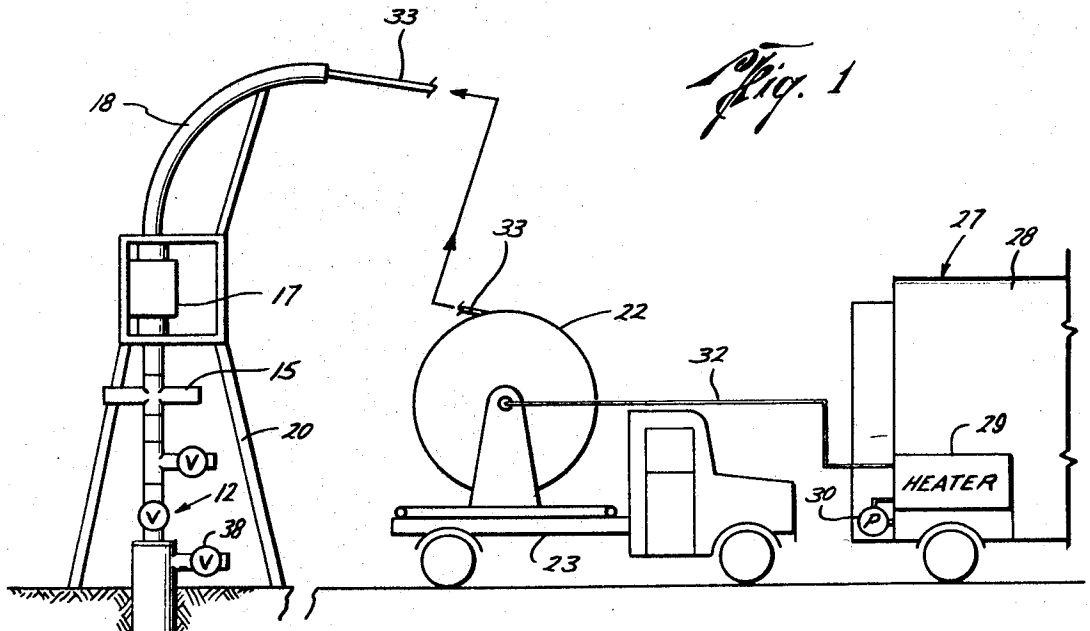
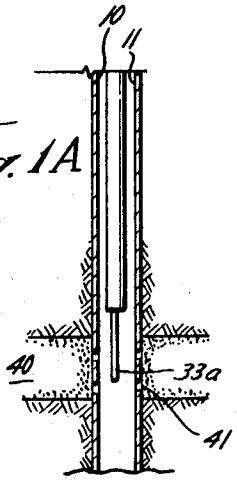



Fig. 1

Fig. 1A



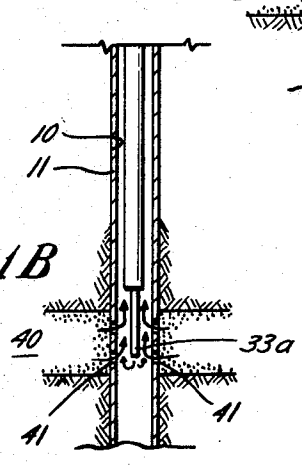




Fig. 1B

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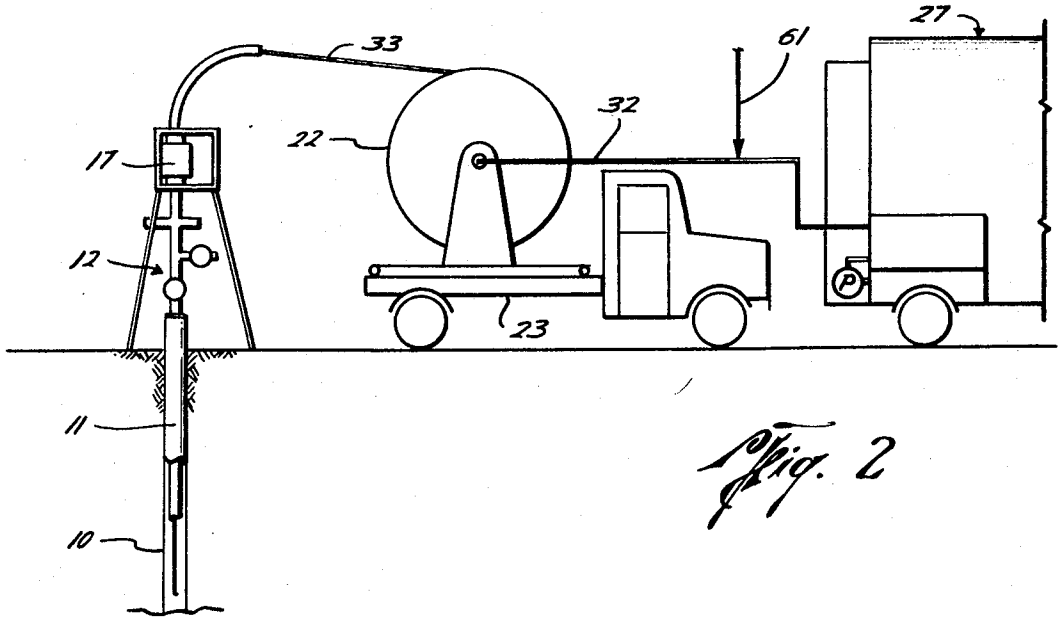



Fig. 2

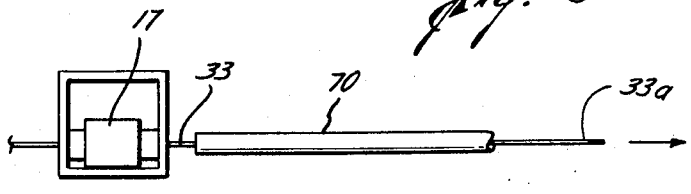



Fig. 3

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# WELL METHODS USING SMALL DIAMETER TUBING

This application is a continuation-in-part of application Ser. No. 873,932, filed Nov. 4, 1969, and entitled "Well Methods Using Small Diameter Tubing", now abandoned.

## BACKGROUND OF THE INVENTION

Injection equipment has relatively recently become available through use of which tubing strings may be introduced into and withdrawn from wells. Such equipment has been developed for use with tubings of ¾ inch to 1 inch diameter size. Apparatus has not been available for introduction of steel tubing of smaller than ¾ inch diameter. However, the equipment which is available may be converted for introduction of the smaller size tubing. According to this invention, ½ inch through ¾ inch outside diameter steel tubing is the preferred size for use, although larger or smaller sizes may be used. According to this invention, use of smaller inexpensive tubing is feasible for introduction of gases into wells for various treatment purposes.

Exemplary of the types of tubing injection apparatuses which are available are those disclosed in U.S. Pat. Nos. 3,116,793, 3,182,877, 3,285,485, 3,258,110, 3,313,346, 3,330,531, 3,346,045, 3,373,816, and 3,379,393. Such apparatuses have not been developed or used in connection with methods such as those herein described.

One object of the invention is to provide well treatment methods through use of which imposition of excessive pressures on well formations during the treatments is avoided, so that fracturing or other break down of the formation is prevented.

Another object of the invention is to provide methods for performing well treatments and operations using small diameter tubings injectable and withdrawable from a well. Other objects of the invention are to provide methods for displacements, for chemical, solvent, and other reagenttype well treatments, and for dewatering or drying of pipelines, shafts, ducts, vents or other conduit systems.

The methods afforded according to the invention are very economical. The small diameter tubing used is of relatively low cost and may be used for long periods of time in a single well or may be used over and over in the same or different wells, as the apparatus employed in connection with the methods is entirely portable. The methods avoid the use of workover rigs and tools where the same would otherwise be required. The methods may be performed very rapidly without lengthy shutdowns or delays being necessary.

Other objects and advantages of the invention will appear from the detailed descriptions of preferred embodiments of the invention and from the accompanying drawings illustrating the methods.

## BRIEF DESCRIPTIONS OF THE DRAWINGS

FIG. 1 is a schematic showing of a displacement method of preferred form according to the invention, and an apparatus useful therewith.

FIGS. 1A – 1B are partial schematic showings illustrating, respectively, progressive fluid displacement and backwash steps of the method of FIG. 1.

FIG. 2 is a schematic showing of the method for reagent treatments in wells according to the invention.



FIG. 3 is a schematic showing of the method for conduit dewatering and drying according to the invention.

## DESCRIPTIONS OF THE PREFERRED EMBODIMENTS

Referring first to FIG. 1 of the drawings, a well **10** has therein one or more casings **11** lining the well hole, and may have other pipes, casings, or tubings therein as required for the purposes of the well, all as well known in the art. Above the well, there is provided a well head **12** which may be of any form employed in the art, the well head including devices for suspending pipes in the well, valves for controlling well pressures, and valve-controlled outlets for providing for flow to and from the pipes in the well. Above the well head, there is a blowout preventer **15**, or other device through which a pipe string may be run without leakage of pressures from within the well. The blowout preventer, or seal, about the small diameter tubing may take the form of a hydraulically activated rubber or elastomeric packoff.

Above the blowout preventer or packoff there is disposed a tubing injector device **17** which may be of any of the forms available in the art, but modified for use with smaller than conventional size tubing, and capable of rapidly running the tubing into a well and withdrawing the tubing from the well. Injector **17** is modified for use with, for example, ½ inch to ¾ inch O.D. (outside diameter) steel tubing. The tubing lengths are welded together at their ends and have no exterior projections. Above the injector **17** there is provided a curved tubing guide **18**. The tubing guides are usually provided with a plurality of rollers rotatable between side guide elements to guide and tubing through a curve or bend when moved longitudinally. Apparatus of the type shown and described in the drawings, of Bowen Tools, Inc., is shown and described in THE OIL AND GAS JOURNAL, Jan. 13, 1964, at pages 72 –73. Other equipment for the same purposes is produced by Brown Oil Tools, Inc.

The tubing injector is supported by a frame **20** which has legs resting upon the ground about the well head. The tubing is stored on a reel **22**, and the reel is equipped so that introductions of fluid to and from the tubing may be made through the reel hub, while all or part of the length of the tubing is wound on the reel or unwound from the reel and injected into a well. The reel **22** is customarily mounted upon a skid unit which may be set on the ground and may be carried on a truck **23** so as to be movable from job to job. As shown in FIG. 1, a liquid nitrogen tank truck **27** has a heater **29** to which liquid nitrogen is pumped by a pump **30**, pressured nitrogen gas being obtained by this cryogenic operation. Liquid nitrogen is first pressured by pump or compressor **30** and is then passed to heater **29** for vaporization whereupon high pressure nitrogen gas is delivered through conduit **32** to the tubing **33** by way of the hub flow connections of reel **22**. Pressured gas exceeding 10,000 pounds per square inch may be obtained in this manner. Other gas may be used for some methods, but nitrogen is safer because of its non-combustible, inert, nature.

In most cases the well **10** will contain a liquid which extends to a level **36** in the well. For displacement of the liquid from the well, the end **33a** of tubing **33** is injected into the well by injector **17** to a position at or

somewhat below liquid surface **36**. The liquid in the well may be of any form, such as drilling fluid, oil, water, or the like. As the lower end **33a** of tubing **33** moves downwardly in the well gaseous nitrogen is continuously introduced at a rate so as to purge and circulate incremental portions of the liquid upwardly from the well through the annulus of a well pipe such as casing **11**, through which the tubing **33** is shown introduced. The liquid in the well may be circulated upwardly through any flow passage in the well through which the gas introduced has access. The liquid circulated out of the well is evacuated through an outlet **38** of the well head. Once the lower end of tubing **33** reaches the bottom of the well, substantially all liquid in the well will have been circulated from the well by the procedure described. Gas introduction may be continuous or discontinuous. It may at times be found beneficial to introduce gas non continuously and to circulate liquid from the well intermittently when the gas is being introduced. The pressure of gas introduced is adjusted to be sufficient to efficiently force the fluid from the well.

After the fluid has been removed from the well, a pressure drawdown exists on the reservoir at the lower portion of the well, the reservoir being denoted by reference numeral **40**. Suitable casing perforations **41** are provided at the area of formation or reservoir **40** so that fluid communication from the well may exist. By pressure drawdown as mentioned above, it is meant that the pressure within the well is reduced so as to be lower than the reservoir pressure.

With the pressure reduced at the formation, as described, when pressured fluids are introduced through the small diameter tubing for treatment of the formation, the pressure of treatment of the formation will be less than the original formation pressure so that the formation is not subjected to excessive pressure which could fracture or otherwise pressure-damage the formation structure. Also, the pressure drawdown enables treatment fluid pressures to be low, not only at the formation but at their point of introduction into the small diameter tubing at the surface. Additionally, the pressure drawdown in the well and at the formation provides that when a treatment is completed the treating fluid is pressure-expelled into the well from the formation, and removed to surface by gas injected through the small diameter tubing, into a low pressure maintained in the well. In other words, a pressure difference is readily created at the formation interface whereby the pressured treating fluid is discharged from the formation into the low pressure of the well.

The nitrogen gas introduced through tubing **33** may be made to flow outwardly from the well through perforations **41** into the reservoir by closing the upward flow path at the top of the well. When the inert gas pressure within the well is released, the nitrogen which has penetrated the reservoir formations returns to the well and cleans materials such as formation fines, precipitates, scale, contaminants, sand, drilling fluids filtrates, reservoir fluids, fluid loss control agents, or any chemical, fluid or solid that may be present in the reservoir through the perforations to be carried to the surface and out of the well.

A pressure differential is created with the aid of nitrogen and is essential for removing the hydrostatic column of fluid that restricts reservoir fluid entry to the formation face or well bore perforations. If necessary or desired, nitrogen may be continuously or intermittently introduced through tubing **33** as the tubing is withdrawn upwardly out of the well so that continual evacuation of fluids above the lower end of the tubing from the well is performed. FIG. **1A** illustrates progressive fluid removal from a well, and FIG. **1B** illustrates the backwash step with return of nitrogen from the formation and up through the well.

As has been stated, use of small diameter tubing strings has been found to be advantageous. The tubing lengths are welded together end to end so that the tubing is smooth and uniform inside and outside. The tubing sizes contemplated are sizes up to and including ¾ inch O.D. nominal tubing size, nominal ½ inch O.D. tubing being about as small as is practical for practice of all methods herein described. Larger or smaller tubing sizes may also be used. While small tubing is not usually practical for use in conveying liquids into and out of wells because of the poor flow rates and high pressure drops encountered, ½ inch O.D. tubing or even smaller tubing is adequate for flow of high pressure gases into (and out of) wells for the purposes of this invention. For example, it has been found that the pressure drop through 10,500 linear feet of ½ inch O.D. tubing at a flow rate of 485 cubic feet of gas ($N_2$) per minute is about 6350 pounds per square inch. But since gas pressures upwards of 10,000 pounds per square inch are available, this pressure drop is not excessive. If water were used instead of gas, pressure drops of the order of 15,000 psi would be encountered. For the methods herein described, gas input rates exceeding 200 cubic feet per minute will not normally be required, but gas input rates as high as 600 cubic feet per minute may be employed with ½ inch O.D. tubing without excessive pressure drops as would occur if water were used.

The cost of smaller tubing is considerably less than the cost of larger tubing, and the tubing reels for smaller tubing are smaller and less costly.

Referring now to FIG. **2** of the drawings, and also to FIG. **1**, the small diameter tubing **33** may be employed for injection of gasified treating fluids or reagents, such as acid, corrosion inhibitors, surfactants, plastics, cement, drilling fluid, alcohol, solvents, or other chemicals used for drilling, completion, or stimulation of the well. Usually the well will be displaced or purged clean with gas before commencement of the treatment. The treating agent is carried by nitrogen or other gas for introduction to the point of the well or to the formation where the treatment is required.

The tubing **33** is run into the well to the desired location and a mixture of nitrogen or other gas and the treating material is introduced therethrough. For this purpose, a side inlet **61** is provided in line **32** for introduction and mixing of the agent with the gas. The high pressure gas is flowed through conduit **32** through the hub flow connections of reel **22** and down through tubing **33** to be exited into the well at the desired location. The active agent may be introduced to any point of the well bore, or into the formation or reservoir through the perforations **41** provided through the well casing. Purging of such materials from the well may be accomplished by nitrogen or other gas injection after

the treatment has been completed, to create the pressure differential across the formation interface described earlier, but often bleeding off of the gas from the well will result in substantially complete removal of such agents upwardly through the well annulus.

The method amounts to a method for spotting or injecting a gasified fluid of the type described into the well with a continuous tubing injector and with continuous agent admixture with the nitrogen or other gas, the nitrogen being the carrying or continuous phase whereas the agent is the carried or discontinuous phase. With nitrogen, the two phase fluid may be injected into the reservoir at minimum injection pressure because of the high relative permeability of gas as compared with liquid. After the well is purged and blown dry with gas such as nitrogen, the two phase fluid is injected into the small diameter tubing string and is carried down to the perforated interval of the casing in an uncontaminated state directly into the reservoir, and at a relatively low pressure with respect to original formation pressure. Drying of the well with nitrogen may be performed as described in connection with FIG. 1 prior to the chemical or other treatment.

As an alternative method, the well may be blown dry of liquid, by nitrogen gas introduced either down through the small tubing string or down through the annular passage between the small tubing and the production tubing within which the small tubing is disposed, followed by introduction of an acid solution down the annular passage above described for acidizing treatment of the formation. When the acidizing treatment is completed, the spent acid is returned to surface through the annular passage by introducing pressured nitrogen through the small tubing string.

As will be realized, various combinations of the described procedures may be practiced in order to achieve the desired treatment of the well, and the exact procedural combinations are exemplary of the various combinations of procedure steps which may be used to gain the benefits of use of the small diameter tubing strings. It will of course be realized that the small tubing strings may be injected, withdrawn, and reinjected, as necessary to the object at hand.

Upon reaching the reservoir, the two phase fluid, nitrogen and agent, is injected into the reservoir to accomplish the purpose of treatment. Only with the aid of nitrogen or other inert gas can a safe two phase injection be accomplished. Another novel aspect of this method is that the hydrostatic weight of the fluid inside the well is removed with the aid of gas and any contaminants or fines present in the fluid are removed from the well prior to spotting the acid or other agent on bottom. The fluid is not bullheaded back into the reservoir as in a conventional treatment. In addition, after the well has been treated, the small tubing in conjunction with nitrogen may be used in removing spent acid or chemical from the well in the same manner as described with regard to FIG. 1.

Referring now to FIG. 7 of the drawings, another method afforded by the invention is useful for dewatering or drying of pipelines, shafts, ducts, vents, or any type of conduit system whether made of steel, plastic, wood, or other material. Referring also to FIG. 1 of the drawings, the heater **29**, or a supplementary heater, is employed for raising the temperature of the nitrogen gas or other gas employed to a temperature sufficient for dewatering and drying purposes. Temperatures up to 1000° F may be used. Then, using injector **17**, the tubing **33** is run into or through the conduit **70** to be dried or dewatered while hot gas is ejected from the end **33***a* of tubing **33** so that complete purging and drying of the conduit system is accomplished. At the same time, suspendable material, liquid or solid, is removed from the conduit by the flow action of the nitrogen or other gas. Conduit **70** may be of any material and may be disposed vertically, horizontally or angularly, and may be straight and/or curved.

While preferred embodiments of the invention have been shown in the drawings, and described, many modifications thereof may be made by a person skilled in the art without departing from the spirit of the invention, and it is intended to protect by Letters Patent all forms of the invention falling within the scope of the following claims:

We claim:

**1**. Method for performing treatments in wells, comprising running a small diameter tubing down a well by means of a tubing injector apparatus, said tubing injector apparatus including a reel for storing the tubing wound thereon and having gas entrance means to said tubing at the hub of said reel, introducing pressured gas into the well through said tubing to perform a treatment in the well, said gas introduction being commenced during running of said small diameter tubing into the well whereby gasification of liquids through which said tubing is run progressively occurs to unload hydrostatic pressure in the well.

**2**. Method according to claim **1**, said treatment comprising displacement of fluid from the well, the well having at least one flow passage therethrough in addition to said tubing, and fluid being displaced from the well upwardly through at least one said additional flow passage by said high pressure gas introduced through said tubing.

**3**. Method according to claim **2**, said pressured gas being nitrogen.

**4**. Method according to claim **1**, said treatment comprising introduction of a reagent into the well, including admixing a reagent with said pressured gas and introducing the mixed gas and reagent through the tubing into the well in gasified form.

**5**. Method according to claim **4**, said pressured gas being nitrogen.

**6**. Method according to claim **4**, said reagent being pressured into the formation by adjusting the pressure of said pressured gas sufficient to penetrate the formation, and subsequently releasing the pressure to allow the spent gasified reagent to reenter the well from the formation.

**7**. Method according to claim **6**, including thereafter introducing pressured gas into the well to dissipate remaining spent gasified reagent from the formation.

**8**. Method according to claim **6**, including thereafter introducing pressured gas into the well to purge the well of said spent gasified reagent.

**9**. Method according to claim **6**, including moving the lower end of the small diameter tubing to at least one additional vertical location in the well, and repeating said treatment.

* * * * *

## Disclaimer

3,722,594.—*Arthur W. Smith*, *Ray A. Plummer*, and *Charles Wayne Johnson*, all of Houston, Tex. WELL METHODS USING SMALL DIAMETER TUBING. Patent dated Mar. 27, 1973. Disclaimer filed, Jan. 2, 1976, by the assignee, *Big Three Industries, Inc.*

Hereby enters this disclaimer to claims 1 and 2 of said patent.

[*Official Gazette March 16, 1976.*]