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Smith et al.

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[54] **WELL PRODUCTION TESTING AND FLOW CHARACTERISTIC EVALUATION METHODS USING SMALL DIAMETER TUBING**

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[21] Appl. No.: **138,140**

Related U.S. Application Data

[62] Division of Ser. No. 873,932, Nov. 4, 1969, abandoned.

[52] **U.S. Cl.**.....**166/250,** 166/264

[51] **Int. Cl.**.....**E21b 43/00,** E21b 49/00

[58] **Field of Search**..166/250, 252, 314, 315, 305 R, 166/77, 264

[56] **References Cited**

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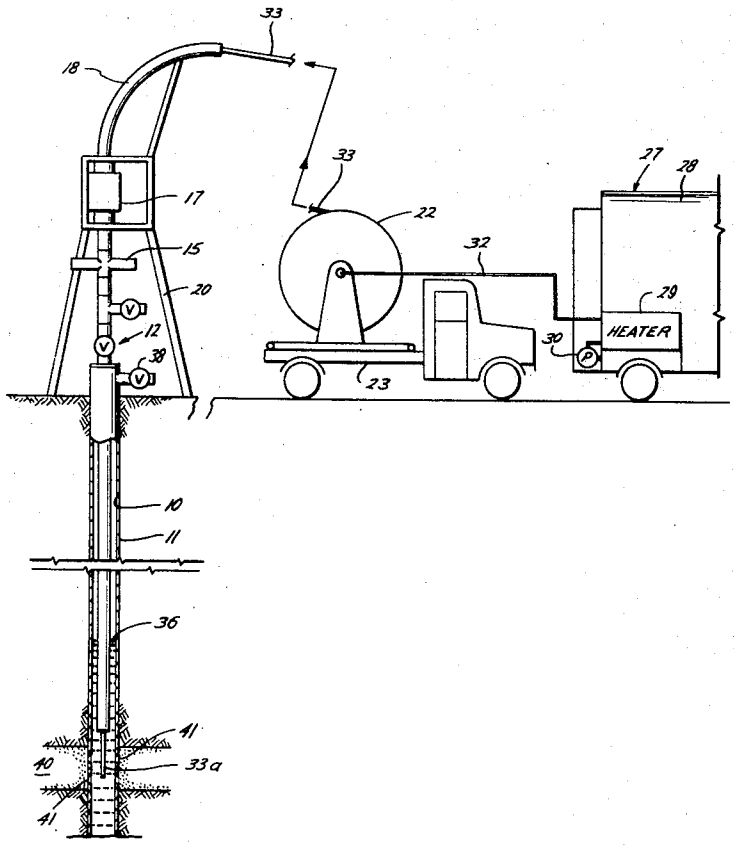
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[57] **ABSTRACT**

Well methods using small diameter tubing introduced into and withdrawn from the well by an injector apparatus. The tubing is introduced into and withdrawn from the well by the injector from a tubing-holding reel. 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. The small diameter tubing is hung in the well with its lower end adjacent the formation to be tested, and injection of gas through the tubing lifts a layer of uncontaminated reservoir fluid to the surface. Continued gas injection accomplishes formation flow characteristic evaluation.

8 Claims, 4 Drawing Figures



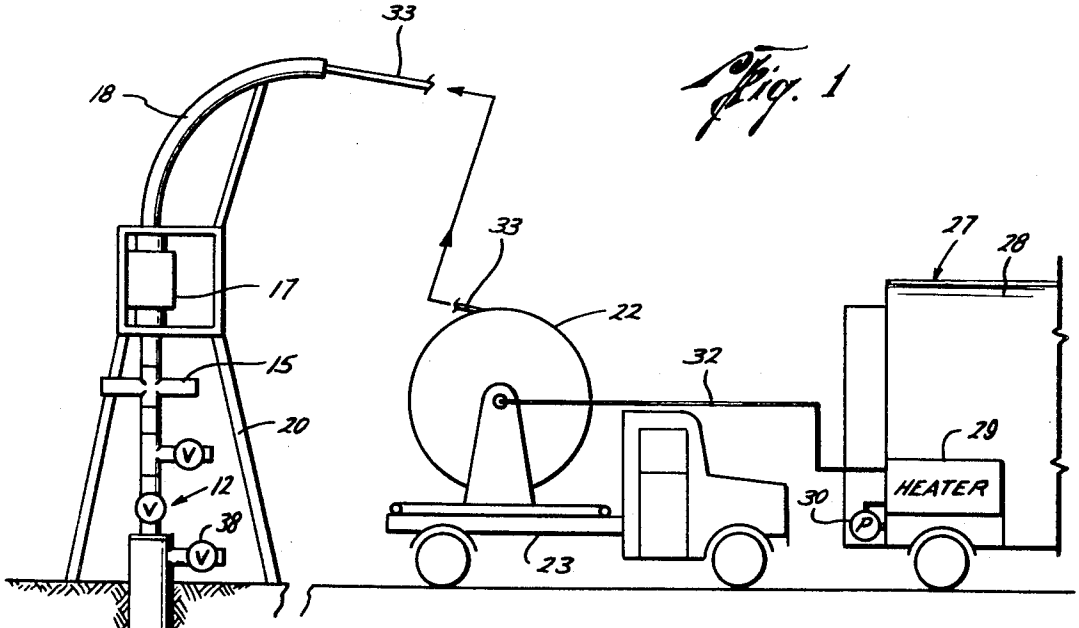


Fig. 1

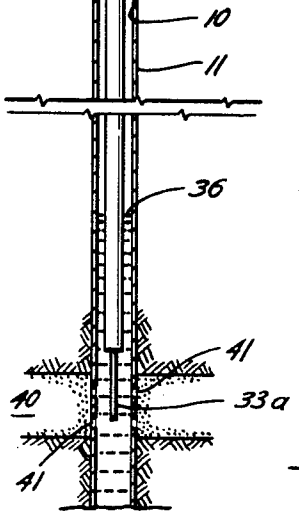
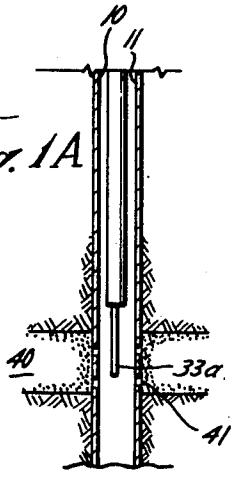


Fig. 1A



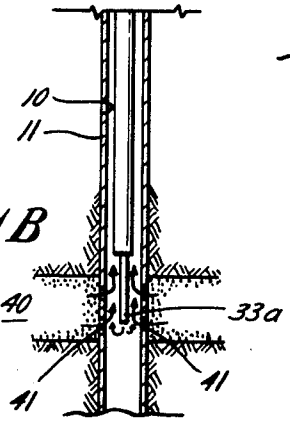


Fig. 1B

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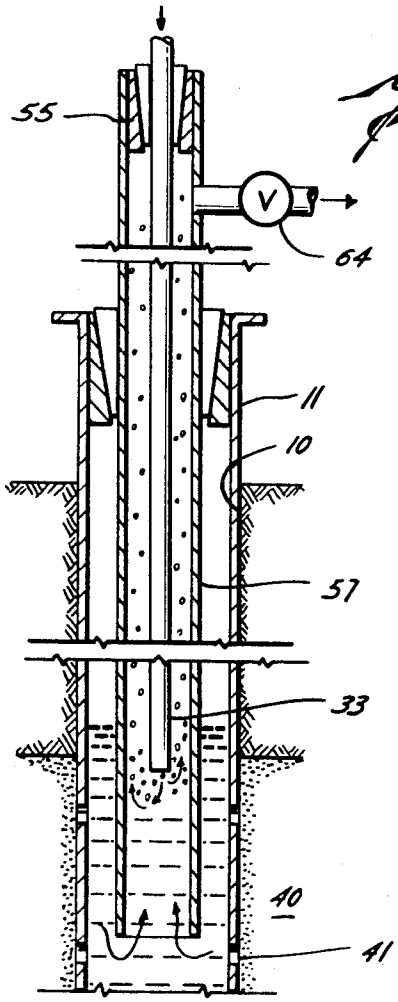


Fig. 2

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WELL PRODUCTION TESTING AND FLOW CHARACTERISTIC EVALUATION METHODS USING SMALL DIAMETER TUBING

This application is a division 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 to 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. 3,182,877, 3,285,485, 3,258,110, 3,330,531, and 3,379,393. Such apparatuses have not been developed or used in connection with methods such as those herein described.

A primary object of the invention is to provide methods for performing well treatments and operations using small diameter tubings injectable and withdrawable from a well, and for production testing and flow characteristic evaluation of the well.

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 shut downs 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 partial schematic showing illustrating methods for production sampling and testing 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 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 the 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 and 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 **33***a* of tubing **33** is injected into the well by injector **17** to a position 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 up-

wardly 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 draw down 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 draw down as mentioned above, it is meant that the pressure within the well is reduced so as to be lower than the reservoir pressure.

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 formation returns to the well and cleans materials such as formation fines, precipitats, scale, shale, 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, smaller than heretofore contemplated in connection with tubing injection equipment, 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 ¾ inch nominal tubing sizes, nominal ½ inch tubing being advantageous for practice of all methods herein described. While ½ inch tubing or smaller 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 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 tubing at a flow rate of 485 cubic feet of gas (N_2) per minute is about 6,350 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 tubing without excessive pressure drops as would occur if water were used.

The cost of ½ inch tubing is considerably smaller then the costs of ½ inch and 1 inch tubing heretofore used with tubing injection apparatuses, and the tubing reels for ½ inch tubing are smaller and less costly.

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 tubing strings may be injected, withdrawn, and re-injected, as necessary to the object at hand.

Referring to FIG. **2** of the drawings, the small diameter tubing herein described is used for methods for production testing a reservoir when a sample of reservoir fluid is required at the surface in an uncontaminated state for formation evaluation. The tubing **33** is injected into the well by injector **17** after the well casing **11** has been perforated as shown at **41** of FIG. **2**. Tubing **33** is hung at a tubing hanger **55** provided for that purpose, the wellhead, only a portion of which is shown, having a valved outlet **64** therefrom having flow communication with the well tubing **57**. The lower end of tubing **33** is positioned adjacent the perforated area, and hung. Injection of nitrogen downwardly through tubing **33** results in lifting a layer of reservoir fluid **61** entering the well from the formation to the surface and out through outlet **64**. The nitrogen injection may be continued sufficiently long to determine the flow characteristics into the well from the reservoir so that production evaluation may be accomplished.

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 production testing of 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, said tubing being run to below the surface of production entering the well from a reservoir, and production testing the well by injecting pressured gas into the production through said small diameter tubing to lift a portion of said production to the surface for recovery in uncontaminated condition.

2. Method according to claim **1**, said pressured gas being nitrogen.

3. Method according to claim **1**, including continuing introduction of said pressured gas and removing

production from the well therewith for a time sufficient to determine flow characteristic evaluation of the well.

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

5. Method according to claim 3, including hanging said small diameter tubing in place during said flow characteristic evaluation.

6. Method according to claim 1, said well having liquid material therein above the surface of production entering the well from a reservoir, and including introducing pressured gas through said tubing while said tubing is being run to below said surface to gasify the liquid material and circulate same from the well prior to production testing of the well.

7. Method according to claim 6, said pressured gas being nitrogen.

8. Method according to claim 1, including hanging said small diameter tubing in place during said production testing.

* * * * *

Disclaimer

3,722,589.—*Arthur W. Smith*, *Ray A. Plummer*, and *Charles Wayne Johnson*, all of Houston, Tex. WELL PRODUCTION TESTING AND FLOW CHARACTERISTIC EVALUATION 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 claim 1 of said patent.

[*Official Gazette March 16, 1976.*]