NEW TOOLS AND CONCEPTS PROVIDE GREATER FLEXIBILITY IN COMPLETING GAS WELLS

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INTRODUCTION

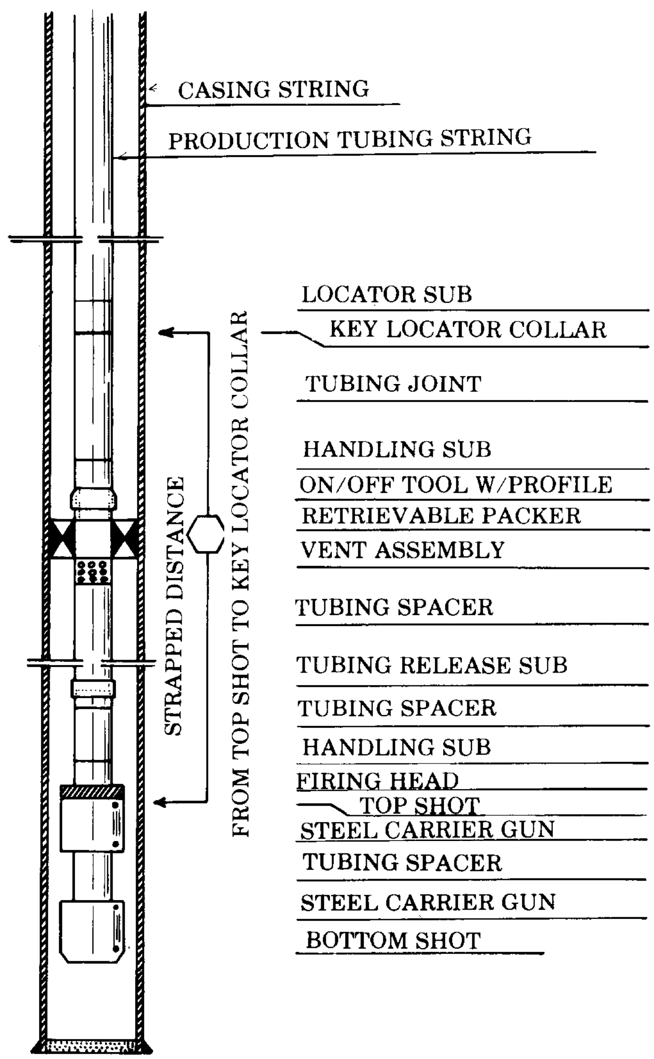
The TUBING CONVEYED Perforating and Well Completion Technique*, which was first introduced by Vann Tool Company in October 1970, has become an accepted and highly desirable method of perforating in southeastern New Mexico and is now being used in wells in West Texas, Oklahoma, Colorado, and Wyoming.

Since its inception, many modifications and improvements have been made in the components and mechanics of the system. In this paper, specific attention is devoted to the following:

1. Accurate and exact depth control for *in-zone* perforating
2. The packer-actuated vent assembly*
3. The mechanical tubing release sub*
4. Safe and effective differential perforating using conventional perforating techniques
5. Communication detection markers for determining the existence of communication between zones.

DEPTH CONTROL FOR "IN-ZONE" PERFORATING

The tubing conveyed perforating technique* offers positive and absolute depth control because the perforating assembly is positioned with respect to the formation. The perforating assembly is strapped as it is installed on the tubing and run into the well. A careful and exact measurement is made and recorded of the distance between the top shot in the perforating assembly and the key locator collar which is the first tubing collar above the packer handling sub, (see Fig. 1). The perforating assembly and the production tubing are tallied into the well and positioned approximately on depth.



*An asterisk denotes the method or components of a system bearing the VANNTAGE trademark.

A thru-tubing correlation gamma ray collar log is recorded to find the exact position of the tubing conveyed perforating assembly* with respect to the open-hole log from which the perforations were selected. The locator sub just above the key locator collar provides a positive means of identifying the key locator collar. A radioactive marker in the key locator collar is recorded on the gamma ray curve, providing a second positive means of identifying the key locator collar, (Fig. 2).

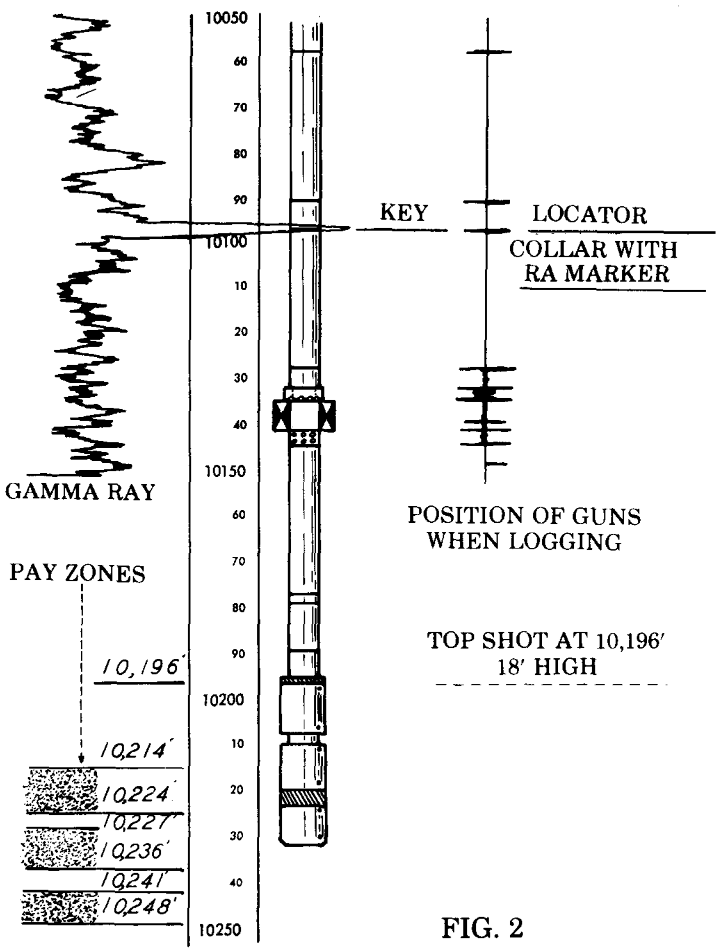


FIG. 2

The desired depth for the key locator collar to be in order to place the tubing conveyed perforating assembly* on depth has been previously determined from the strapping of the assembly into the well. By locating this collar and its depth with respect to the formation on the open-hole log it is then determined exactly how much to raise or lower the production tubing string to place the tubing conveyed perforating assembly* on depth, (Fig. 2).

The necessary footage is then added to or subtracted from the tubing string and the production packer is set, placing the tubing conveyed perforating assembly* on depth exactly opposite the zone or zones to be perforated, (Fig. 3).

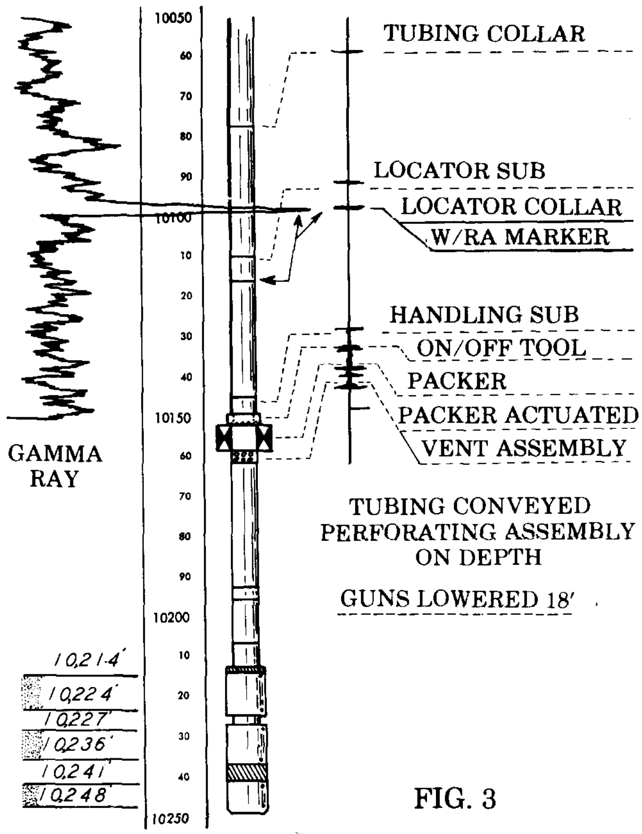


FIG. 3

IN-ZONE PERFORATING

The use of the tubing conveyed perforating technique* to achieve "in-zone" perforating and "in-zone" production is highly desirable and practical. The perforating guns are run on the bottom of the tubing below the production packer and in most instances remain in the well after detonation as part of the tubing tailpipe. Since the perforating guns remain on bottom, a jet charge can be used which is more powerful than the charges used in perforating with thru-tubing guns. In instances where the tubing string is run dry, as in the Morrow wells in southeastern New Mexico, the perforating is done with a zero water blanket allowing maximum pressure differential toward the well bore at the instant of perforating. Since the wellhead has been completely tested, installed, and flanged up prior to detonating the guns, a "cased-hole drill stem test" or controlled blow-out occurs while maintaining absolute safety and pressure control.

The deeper penetration of the larger jet charges in the casing guns, as compared to the charges in thru-tubing guns, penetrates the worst part of the filtrate damage. The rapid movement of the gas or oil back through the perforations into the casing employs the available energy or formation pressure in a sweeping, cleaning action on the drilling fluids, filtrate and cement damage; and in most instances results in the perforations becoming a good clean pipeline from the virgin reservoir to the casing.[1] In many cases the need for stimulation is eliminated and a natural completion is achieved. All that remains is to potential the well and put it on production.

In wells which require stimulation, the producing gases or fluids come from throughout the treated zone. Since the need for treatment is eliminated in most tubing conveyed* completions, the producing gases or liquids are more likely to be coming from the perforated zones only. Thus the technique discussed above could be called "in-zone" perforating.

PACKER ACTUATED VENT ASSEMBLY*

In March 1973, the packer actuated vent assembly* was developed to be used in conjunction with the tubing conveyed perforating technique.*

The tool, which is actuated by the relative movement of the mandrel to the hull of the packer, is adaptable to most retrievable production packers and consists of three parts, (Fig. 4):

1. An outer hull which becomes a part of the packer hull to which it is attached
2. An inner stem or mandrel which becomes an extension of the packer mandrel
3. A positive control sliding sleeve.

Prior to the development of this tool, the most commonly used methods of running the tubing dry were to run a retrievable blanking plug or to displace with nitrogen or CO_2 before setting the packer. While these methods have all been used successfully, the packer actuated vent assembly* has proved to be less expensive, safer, and less time-consuming than other methods, and is more adaptable to and compatible with the tubing conveyed perforating technique*.

The packer actuated vent assembly* is attached to the packer and run with the sliding sleeve closed, keeping the tubing dry and at the same time providing an external leakage test for the

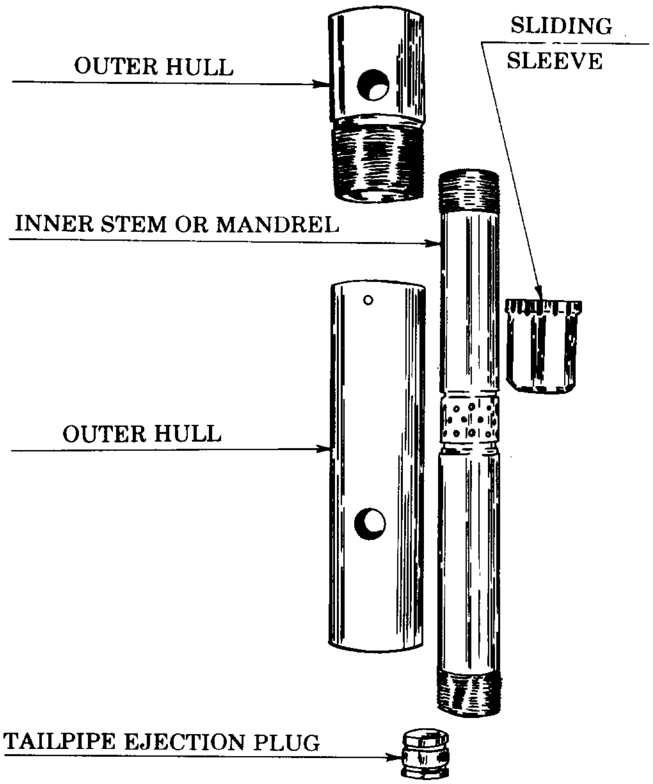


FIG. 4—PACKER ACTUATED VENT ASSEMBLY*

tubing string. When the packer is set, the downward travel of the mandrel causes the sleeve to engage the outer hull of the vent assembly*. At the moment the packer begins to "pack-off," the trapped hydrostatic pressure below is slowly relieved through some small "bleeder ports" in the vent assembly*. As the packer takes additional weight, the downward movement of the packer mandrel opens the sliding sleeve, revealing the ports in the stem of the packer-actuated vent assembly* which now becomes the perforated nipple for the production tubing string.

Be relieving the trapped hydrostatic pressure in this manner, a retrievable, tubing-set packer "packs off" in much the same manner as a hydraulically set packer run on wire line. The result in a much better packer seal; the packer is still retrievable with the tubing string, and the packer has been tested for leakage. If there is no vacuum in the annulus after the packer has been set, you can be assured the packer is holding. This is carefully checked before the guns are fired.

The packer actuated vent assembly* is available for either 2-3/8 in. OD or 2-7/8 in. OD tubing. The cross-sectional flow area of the ports is greater than the ID of the production tubing. Therefore, the ports present no downhole restriction to production flow.

This tool was originally run only in conjunction with tubing conveyed perforating* operations but has since been adapted to conventional completion operations.

SAFE AND EFFECTIVE DIFFERENTIAL PERFORATING WITH CONVENTIONAL TECHNIQUES

A well can be perforated with a wireline casing gun with the hydrostatic head pressure balanced or slightly underbalanced. Casing guns are recommended in order to achieve the deepest possible penetration. The packer actuated vent assembly* is run closed below the retrievable production packer. The tubing is kept dry by means of a drillable tailpipe ejection plug installed in the bottom of the vent assembly*, (Fig. 4).

When the packer is at the desired depth, the blow-out preventer is removed and the wellhead installed on the tubing. The packer is then set with a tubing swivel in order to keep the well under absolute control. As the packer "packs off" and the vent assembly* opens, the well is allowed to flow immediately and unrestricted toward the surface. In doing so, this procedure allows the formation to explode into the casing, providing an immediate clean-up of the perforations in a manner similar to the "implosion effect" created by tubing conveyed perforating*.

The tailpipe ejection plug is expelled as the packer sets, leaving the tubing open-ended. In the event the tailpipe plug does not eject, the diameter of the ports in the vent assembly* allows for stimulating the well with no restriction of reduction of rate down tubing. Thus, no problem exists if the plug remains in place unless it is desired to use ball sealers or some other diverting agent.

In that situation it is recommended that a small drillable bar be dropped from the surface or a sinker bar be run on wire line to assure that the tailpipe ejection plug has been expelled. If the plug is still in place, the bar will knock out the plug leaving the vent assembly* open-ended for the ball sealers to exit.

MECHANICAL TUBING RELEASE SUB*

In some instances of tubing conveyed perforating* where a well requires stimulation, it is desirable to have the tubing open-ended in order the ball sealers or other diverting agents may be used. While the packer actuated vent assembly* allows for acidizing the well through its ports with no tubing restriction, the design of the tubing conveyed perforating assembly* does not allow for the use of ball sealers while the guns are in place opposite the perforations.

The tubing can be cut off below the packer and the guns dropped into the rat-hole in order to be open-ended, but the advantage of eliminating the guns in this manner without unseating the packer also has some disadvantages:

1. Tubing cutters are not always dependable.
2. The tubing-cutting operation requires pressure control and lubricator equipment resulting in
3. Higher completion costs.

The mechanical tubing release sub* provides a safe, economical, and dependable means of releasing the guns quickly and easily. The tool, which has an ID of 1.90 in., can be run anywhere between the packer-actuated vent assembly* and the perforating guns. Normally, it is recommended that it be run at least 15-20 ft above the top shot which gives ample room for ball sealers to perform effectively.

A slick-line unit with an appropriate shifting tool shifts an internal latching device or releasing mandrel *upward* causing the tubing release sub* to separate. The weight of the guns causes them to fall into the rat-hole leaving the tubing open-ended. (NOTE: The tool is designed so that only the appropriate shifting tool can move the internal latching device. There is no risk of accidentally releasing the guns by other wireline tools that might be run through the tubing release sub*.

Since this operation can be performed with a slick-line unit it is not necessary to have a pulling unit on location. The need for costly pressure-control equipment (grease injector, etc.) is eliminated. These benefits and the benefits of tubing conveyed perforating*, combined with the nominal cost of the tubing release sub*, make this a safe, effective and economical means of perforating with maximum pressure differential *toward* the well bore if desired, maintaining maximum pressure control, and leaving the tubing open-ended for stimulation without risking further fluid damage to fluid sensitive zones.

The tubing release sub* can be utilized equally well in situations where high bottomhole pressures cause tubing conveyed perforating* to be desirable because of the safety aspects achieved through absolute pressure control.

COMMUNICATION DETECTION MARKERS

Vann Tool Company offers two kinds of communication detection markers: casing-to-cement and cement-to-formation. These tools offer a revolutionary method of detecting communication between zones when using acid stimulation in oil or gas wells. The method is basically simple in design and principle; yet it can remove all doubt as to whether communication has occurred between pipe and formation and if so, in *which direction* it occurred. In many cases it is also possible to determine which formation took treatment.

The communication detection marker or "CD Tool" is in the form of a specially designed slip-on collar attached to the outside of the casing (for casing-to-cement markers) or a specially designed centralizer (for cement-to-formation markers). These special collars protect the carrier for the minute amount of liquid radioactive isotope used. The carriers in the collars encompass the entire circumference of the casing. The liquid radioactive isotope contained in these special collars and centralizers can be readily detected on a gamma ray log. The carrier for the RA material is easily decomposed by hydrochloric acid.

These markers are placed on the outside of the casing string in any desired combination or interval. By keeping a careful tally of the casing string, a series of markers can be placed above and below the zone or zones to be perforated and acidized. They will be clearly visible on the gamma ray depth control log as evidence they are in place at the desired intervals, (Fig. 5).

During treatment, should there be any communication of the acid treatment fluid, either between cement and casing or cement and formation, the acid treating fluid will contact the communication detection marker. The radioactive isotope carrier will be decomposed and the liquid RA material will be carried away by the fluid stream.

The fact that communication has occurred and the direction in which it occured can be easily determined by running another gamma ray log. This second log can be recorded through tubing if desired since it is possible to log through both the tubing and casing strings. Provided enough markers are installed on the circumference of the casing string, it can also be determined how far the treating fluid traveled and where the treatment entered the formation. At least six markers spaced approximately 30 ft apart both above and below the zone or zones to be perforated is recommended.

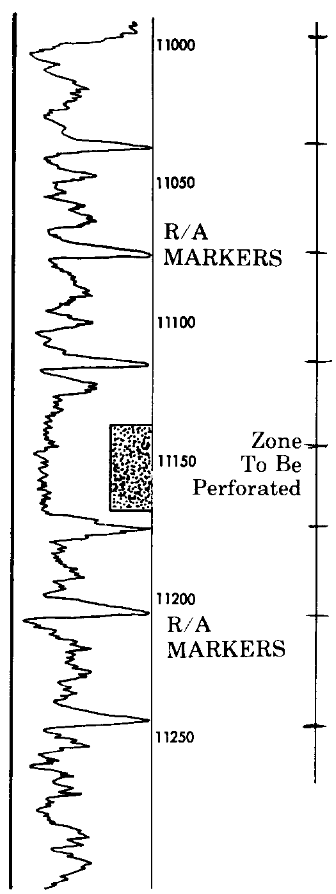


FIG. 5—CASING GAMMA RAY BEFORE TREATMENT

A comparison of the second gamma ray log with the original cased-hole log will show which markers are missing with respect to the perforated zones, (Fig. 6).

As shown in Fig. 6, the RA marker at 11,037 ft is still in place on the second gamma ray log. The markers at 11,075 ft and 11,115 ft in Fig. 5 are no longer visible on the log in Fig. 6. Therefore, communication did occur in an *upward* direction with the treating fluid entering the formation between 11,037 ft and 11,075 ft.

The use of this quantitative information enables the operator to perform necessary remedial work prior to proceeding with a costly ırac job which would probably follow the same path as his acid treatment.

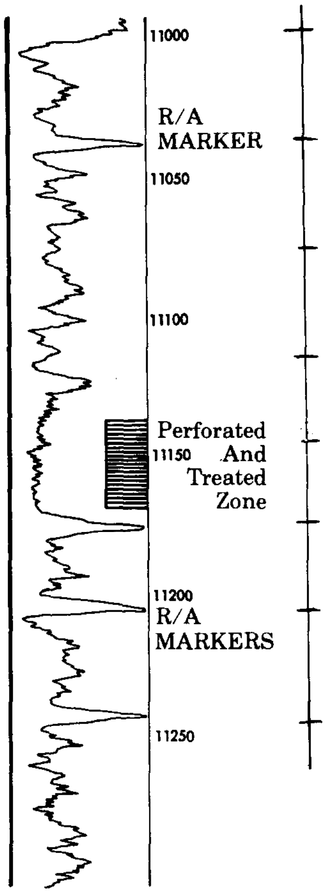


FIG. 6—CASING GAMMA RAY AFTER TREATMENT

REFERENCE

1. Yeates, R.D. (Bob): Morrow Sandstone Well Completion Practices, *Southwestern Petroleum Short Course Proceedings,* Apr. 1974, pp. 19-24.