TUBING-CONVEYED, HIGH-TEMPERATURE, DEEP WELL PERFORATING

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Previous research and publications have established that clear and effective communication between the casing and the reservoir formation is an absolute requirement for an effective oil or gas well completion.[1] As wells are drilled deeper and casing strings become smaller, the ability of jet perforating guns to penetrate the well bore effectively is greatly reduced.

In wells exceeding 15,000-foot depths one or more of the following situations usually exist:

1. Combination casing strings involving small bottomhole ID
2. The necessity of using small perforating guns due to well design
3. High compressive strength rocks which decrease the penetration of jet guns
4. High bottomhole temperatures which can reduce the penetrating effectiveness or performance of the perforating gun and in some cases render it inoperable
5. Excessive completion costs due to items 1 through 4.

Because of these factors, the completion of such wells successfully, safely, economically, and satisfactorily has become an ever-increasing challenge. Present completion techniques of perforating usually employ the use of a shallow-penetrating jet perforating gun run on wire line. When penetration is not sufficient, hydraulic treatment is needed to complete the well. Hydraulic treatment can be costly, and in some instances, possibly damage the production zone.

In a unique modification of its field-tested and proven TUBING CONVEYED Perforating Technique, Vann Tool Company has devised what is believed to be a safe, effective means of perforating deep, high-pressure wells with abnormally high bottomhole temperatures. This method is called the VANNTAGE® High Temperature TUBING CONVEYED Perforating System. It is now ready for field testing.

COMPONENTS AND MECHANICS OF THE SYSTEM

When it has been determined which zone or zones in the well are to be completed and production casing has been run, a gamma ray correlation collar log is run in casing. Using this gamma ray correlation log for positive depth control, a drillable bridge plug is installed at a predetermined and carefully measured distance *below* the bottom of the zone to be perforated. This bridge plug serves as an abutment member or gun stop to be later used in detonating the tubing conveyed perforating assembly. (See Fig. 1) The components of the perforating assembly (from bottom to top) are as follows:

1. Percussion detonated firing head*
2. Steel carrier perforating guns (loaded 1, 2, 3 or 4 jet shots per foot as desired)
3. Tubing spacer
4. Mechanical or pressure-actuated tubing release assembly*
5. Tubing spacer
6. Wireline-set production packer
7. Production tubing string
8. Christmas tree with lubricator and valve for wireline work.

After the gun stop has been set, a wireline-set production packer is positioned up-hole at a

*An asterisk denotes a component of the TUBING CONVEYED perforating system bearing the VANNTAGE trademark.

predetermined location. The positioning of this packer has been previously determined to be at a depth where borehole temperature does not damage the packing elements. In most cases, we could expect that a large-bore packer would be set near the top of the liner, Fig. 1.

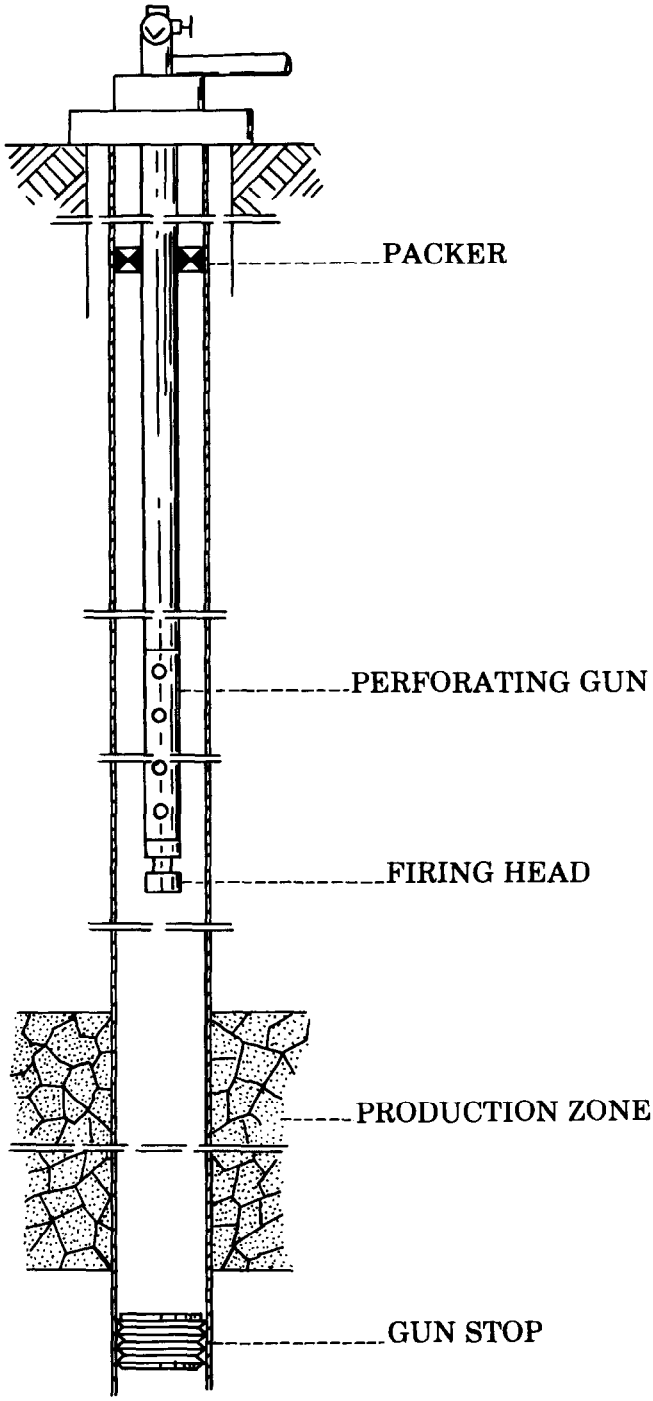

FIG. 1

The components of the tubing conveyed perforating assembly* are then installed on the production tubing string and run into the well. (Due to the high bottomhole pressures encountered in deep holes, most tubing strings are run wet; however, by utilizing a profile and blanking plug, a string can be run "dry" if desirable. In this case the blanking plug would be retrieved by slick-line unit prior to releasing the guns.)

The tubing conveyed perforating assembly* is stung into the packer, sealed off, and the wellhead installed at the surface. (NOTE: a large-bore wireline-set packer allows for the passage of the tubing conveyed perforating assembly* *through* the packer, thus making it simple to retrieve or "fish" the perforating assembly should it become desirable to do so.) When the tree has been installed and flanged up at the surface, the well is ready for perforating.

Using a lubricator of sufficient length to allow for the full tool length, a slick-line unit equipped with hydraulic jars and the appropriate shifting device is used to mechanically release the mechanical tubing release assembly*. The steel carrier guns drop, the percussion-detonated firing head* strikes the gun stop at the bottom of the zone, and the guns fire. (NOTE: The distance between the bottom shot and the bottom of the firing head is carefully measured in advance. Since the depth of the gun stop with respect to the zone to be perforated is already known, the bottom shot in the perforating gun can be placed exactly, thus achieving positive depth control for *in-zone* perforating.)

Any production in the perforated zone is now free to flow immediately to the surface, displacing the column of fluid in the tubing and maintaining absolute pressure control. When the production flow and pressure have stabilized in the tubing, the slick-line unit removes its tools from the well and the well is now ready to be cleaned and tested.

The steel carrier gun which is centered, remains on bottom immediately above the gun stop in the casing, (Fig. 2). The presence of the discharged gun downhole adjacent the producing formation is beneficial because the pressure flow from the perforations strikes the gun housing rather than the casing. Thus, an "internal blast joint" is installed downhole, with the gases diverted up the annulus formed between the gun and casing, thereby avoiding erosion of the inside wall surface of the casing in proximity of the production zone.

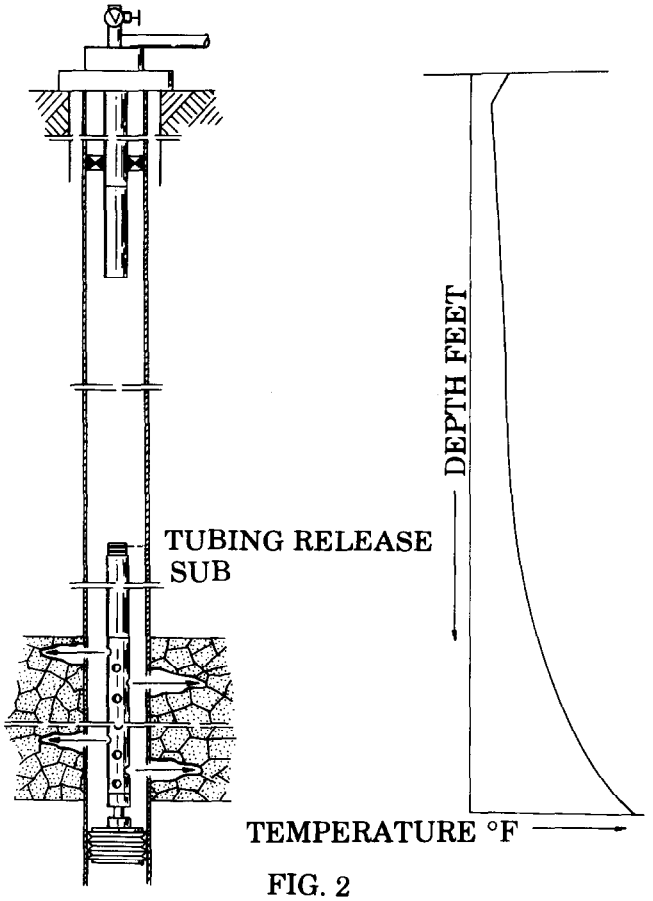

FIG. 2

In the event it is not considered desirable to have any wire line in the well at the time of perforating there is another method available to release the guns. A pressure-actuated tubing release sub* is substituted for the wireline-actuated mechanical tubing release sub*. The pressure-actuated tubing release sub* has an inner piston which is hermetically sealed within the tubing release sub*. The guns are released by pressuring up on the tubing string with fluid or gas. The rate of descent of the tubing conveyed perforating assembly* can be regulated by the design of the gun-centering devices.

APPLICATION

This system would offer the following advantages:

1. The use of a larger jet gun for deeper penetration of high compressive-strength formation
2. Prolonged exposure of the perforating gun to high bottomhole temperatures has been eliminated, thus improving the performance of the jet perforating gun.
3. The use of electric line in perforating has been eliminated, avoiding possible leaks in wireline pressure control equipment. (NOTE: Guns are designed so they can be fished from hole with wire line.)
4. The safety of absolute well control.

REFERENCE

1. Weeks, S.G.: Formation Damage or Limited Perforating Penetration? Test-Well Shooting May Give a Clue, *Jour. Petr. Tech.*, Sept. 1974, pp. 979-984.