USE OF TUBULARS FOR EFFECTIVE COMPLETIONS

CHARLES W. KINNEY
GEO Vann, Inc.

ABSTRACT

This paper serves to up-date applications and results of the Vannsystem. The Vannsystem is the process of running large casing guns on tubing for maximum completion performance.

Prior papers on this system have dealt primarily with maximum differential perforating to overcome formation damage. The 3,000 plus wells completed using this technique included such applications as tight gas sands, highly unconsolidated sands, intervals of several hundred feet, formation evaluation, off-shore, injection wells, and others. Recent key applications, along with case histories, will be reviewed. The use of tubulars makes it possible to customize completions under such a variety of conditions.

INTRODUCTION

This paper represents a status report on Vannsystem jobs. The emphasis is primarily on applications and not relative performance.

The Vannsystem is a completion method whereby casing perforating guns are conveyed into the well on tubing as opposed to the conventional wireline technique. The often heard trademark for this perforating gun assembly is "Vannguns". The term Vannsystem has been broadened to include many applications and hook-ups using Vannguns and tubing together in the same well. Thus, the well installation may be permanent or temporary, but the common factor is the use of casing guns for perforating.

Over 3,000 jobs have been performed utilizing the Vannsystem. About 2/3 of these jobs, or 2,000, have been run since the Fall of 1978. Thus, the Vannsystem has been utilized in many different applications since 1978 and since previous papers were published on this system.

BASIC VANNSYSTEM HOOK-UP

The original, or basic, Vannsystem installation is shown on Fig. 1. From bottom to top are casing perforating guns, a mechanical releasing device, a packer actuated vent assembly, a retrievable packer, and a short tubing sub with a radioactive marker in the lower collar. This is for the purpose of logging the guns exactly on depth as explained from Figs. 2 and 3. As many casing perforating guns as may be required are run in on the tubing. When the approximate depth has been reached, a small diameter through-tubing correlation tool and collar locator are run to log the guns on depth. A short section of log is made across the sub containing the radioactive marker, which is readily visible when picked up on the log. This log is then correlated to the open hole log and the position of the equipment is accurately determined. At the proper depth, the packer is set and the guns are in the exact perforating position. When the packer sets, the patented packer actuated vent assembly is opened. Since this vent assembly is actually run in the closed position, the tubing may be run dry or partially filled with water depending on the cushion desired. When the packer is set and the vent assembly is opened, the pressure below the packer in the wellbore, and that inside the tubing, are equalized and thus the desired differential or underbalance for perforating is established.

After the well head is installed, a detonating bar is dropped down the tubing to fire the Vannguns mechanically. When the casing is perforated, any hydrocarbons in the adjacent formation will surge into the wellbore, up the tubing casing annulus, through the vent assembly, into the tubing, and to the surface. Installations are designed to be either temporary or permanent. Should, for any reason, it be desired to have open-ended tubing, the guns can be dropped off into the rathole by actuating the mechanical tubing release device.

CONTROLLED DIFFERENTIAL PERFORATING

In order to understand more readily some of the applications that I will be describing in this paper, it is first important to realize that this system is flexible and facilitates adjusting to a wide variety of reservoir and wellbore conditions. Almost every day this system is used to complete wells by perforating with balanced pressure conditions, as well as maximum differential pressure conditions. There are reservoirs that are relatively unconsolidated and/or that have fines (clay) that can move through the reservoir. Under high flow rates, or surging conditions, flow of fines or sand can cause plugging in the reservoir adjacent to the wellbore. When this condition exists, the differential under which perforating is carried out is controlled, as well as flow rates to properly bring the well in. However, after completing over 3,000 wells, we have found that many reservoirs are not as critical in terms of low rates and surging as earlier expected. One example is the Wilcox formation in South Texas. The Wilcox has been described as having a fines movement condition; however, it has proven to be one of the most successful in performance for high differential perforating. The average differential for a Vannsystem completion in the Wilcox of South Texas exceeds 2000 psi. In fact, the maximum differential is used in virtually all completions. We are no longer concerned about high differential perforating causing damage in competent formations. We commonly perforate with 3500 psi to 5000 psi differentials.

Figs. 4 and 5 are used to illustrate the guidelines by which we establish differentials. Mud damage exists to some degree of severity in every well that is drilled. The depth of such invasion may not be known in every case. The zone of invasion, however deep, represents 100 percent water saturation. Therefore, the relative permeability to oil or gas is zero. Obviously, a much greater resistance to flow exists than in the uncontaminated formation. Routinely, we see this resistance to flow measured in excess of 2000 psi. On occasion, it is seen as high as 5000 psi. This means that if less differential is used when perforating, no flow will occur. Not only is it our practice to exceed this resistance in differential, we like to exceed it by some margin that will enable the well to kick the fluid out of the hole once it is surged through the perforations and into the wellbore. Obviously, the bottom hole pressure and gas volume may not be sufficient to flow to the surface. However, the important thing is to flow it into the wellbore where it can at least be removed by artificial means.

The jet perforator also adds a restrictive barrier to flow. This is in the form of a compacted zone that envelops the perforation. The differential pressure required to break loose this layer varies significantly, and especially in gas reservoirs, can readily exceed modest underbalances often used when perforating.

Figs. 6, 7, and 8 will show some cases where maximum differential perforating has been used. Case Number 5 had an offset well that was still rate sensitive after 6 months. Rather than to believe the PI varies drastically between offsets, we feel the primary difference in productivity is the degree to which a well is cleaned up. Some wells have remained rate-sensitive for months and even years.

Such successful practice leads us to believe that, as a general statement, the higher the differential, the better the completion. We carry this even further believing the more holes, and the larger the holes, as well as the deeper the penetration, the better the completion.

WELL TESTING

The tremendous boom in gas exploration over the past several years has given rise to substantial development in well testing, and in particular, pressure build-up analysis. The Vannsystem is finding wide use in wells to facilitate such testing. (See Fig. 9.) The Vannsystem has been used specifically in gas wells to be tested because of the values necessarily obtained from build-up analysis curves. The Vannsystem serves as a cased hole test string. In a Vannsystem gas well completion, a flow of gas is virtually always obtained, even in wells where fracing is pre-determined. Such flow rates can generally provide accurate data. A minimum flow rate can be established without disturbing the reservoir by treating. Thus, a good build-up curve can be obtained and accurate Kh values determined. These Kh values have proven desirable, especially for predicting post-frac performance.

LONG INTERVALS

The Vannsystem is gaining widespread use for completing long intervals. There are two primary reasons for this: (See Fig. 10)

1. All perforations under a typical Vannsystem hook-up can be surged and the wellbore cleaned throughout the interval;

2. Considerable rig time can be saved, particularly in offshore highly deviated wells.

Long intervals are typically 100 ft. to 250 ft. However, there have been a number of wells 300 ft. to 400 ft. and two wells over 600 ft. Vannsystems with Vanngun assemblies in excess of 1000 ft. are being planned for the near future. The long interval jobs are occuring primarily offshore in thick solid zones, including injection wells. Inland wells, where long Vanngun assemblies have been run, have consisted of many zones spaced out over long intervals with production comingled. Completion efficiency from perforating all zones at once will often warrant killing the well and pulling the equipment rather than perforate the zones separately.

HIGH SHOT DENSITY

High shot density perforating has become a large percentage of Vannsystem completions. Most applications are in offshore wells wherein we see both highly deviated wells and high volume producers, many of which require sand control measures.

Fig. 11 shows a special high shot density hook-up. This installation is being used to perforate long, unconsolidated intervals in heavy oil sands. These wells are generally highly deviated. Each Vanngun assembly will span approximately 250 ft. The Vanngun assembly and associated equipment is run in on drill pipe, the perforating is performed at balanced or essentially balanced pressure conditions, and the equipment immediately pulled from the well. This procedure is being carried out in 12 hours. The operator has 12 shots per foot through which he is gravel packing. The main reason the installation is made is that it takes 12 hours whereas perforating the same zone with 8 shots per foot by wireline takes 60 hours. A standard application is being made on the Gulf Coast, as can be seen in Fig. 12. In this case, however, a packer was used and the perforating is carried out under approximately 300 psi differential. The wells are thus being flowed for clean up as opposed to other conventional methods of separate surging or perforation washing. The results of 2 cases are shown in Fig. 13.

It is anticipated that high shot density perforating will increase substantially. It is being recognized that greater flow area at the formation face can cause both increased production and less sand flow. Greater flow area simply enables the formation to produce a given amount of fluid at less velocity into the wellbore. In many cases, sand flow was reduced or less than that observed in offset wells.

Shot pattern, as can be seen in Fig. 14, is proving to be of key importance to flow characteristics in the formation at the wellbore. More holes in a single plane improve flow patterns and result in less turbulence at the wellbore. It also enhances production throughout the zone when natural formation sensitivity and low or no vertical permeability exists.

SHOT DETECTION

Certain well conditions make it difficult to determine if the Vannguns have fired. Obviously, one of those conditions is if there is no response from the well and the tubing has been run dry. The primary reason is where the tubing is full of fluid and any response might be held back. Fluid in the tubing also adversely affects other possible surface indication.

A new device is proving highly successful in detecting Vanngun firing. It is merely an extremely sensitive geophone-type instrument. A sensor is attached to the wellhead. The sensor is connected to a two-touch recorder which can both tape the sounds and broadcast them over a speaker. The sounds are quite clear and distinguishable when the bar is falling through the tubing, when the bar hits the fluid, and when the bar hits the firing pin and fires the guns. There have been a number of cases when the shot detection system proved Vanngun firing when no surface indication was observed.

REFERENCES

1. Vann, R. R., Sr., and Owens, Ray: "New Tools and Concepts Provide Greater Flexibility in Completing Gas Wells", paper presented at 22nd Annual Southwestern Petroleum Short Course, 1975.
2. Anon.: "Completion Method Reduces Effect of Formation Damage," World Oil (Nov. 1975) 66-70.
3. Brieger, E. F., and Stovall, G.: "Perforating Damage: Here's One Field Tested Solution", World Oil (July 1976).
4. Weeks, S. B.: "Formation Damage or Limited Perforation Penetration? Test-Well Shooting May Give A Clue", J. Pet. Tech. (Sept. 1974) 979.
5. Suman, G. O., Jr.: "Perforations - A Prime Source of Well Performance Problems", J. Pet. Tech. (April 1972) 399.

6. Bell, W. T., Brieger, E. F., and Harrigan, J. W., Jr.: "Laboratory Flow Characteristics of Gun Perforations", J. Pet. Tech. (Sept 1972) 1095.
7. Colle, Ed A., Jr.: "A Completion Technique For Overcoming Formation Damage", paper presented at Third Symposium on Formation Damage Control in Lafayette, Louisiana, 1978.

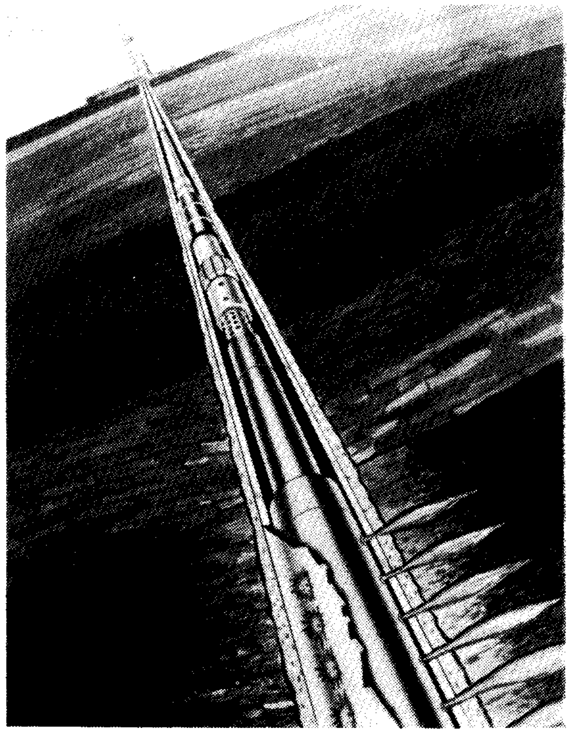

FIGURE 1—BASIC VANNSYSTEM INSTALLATION

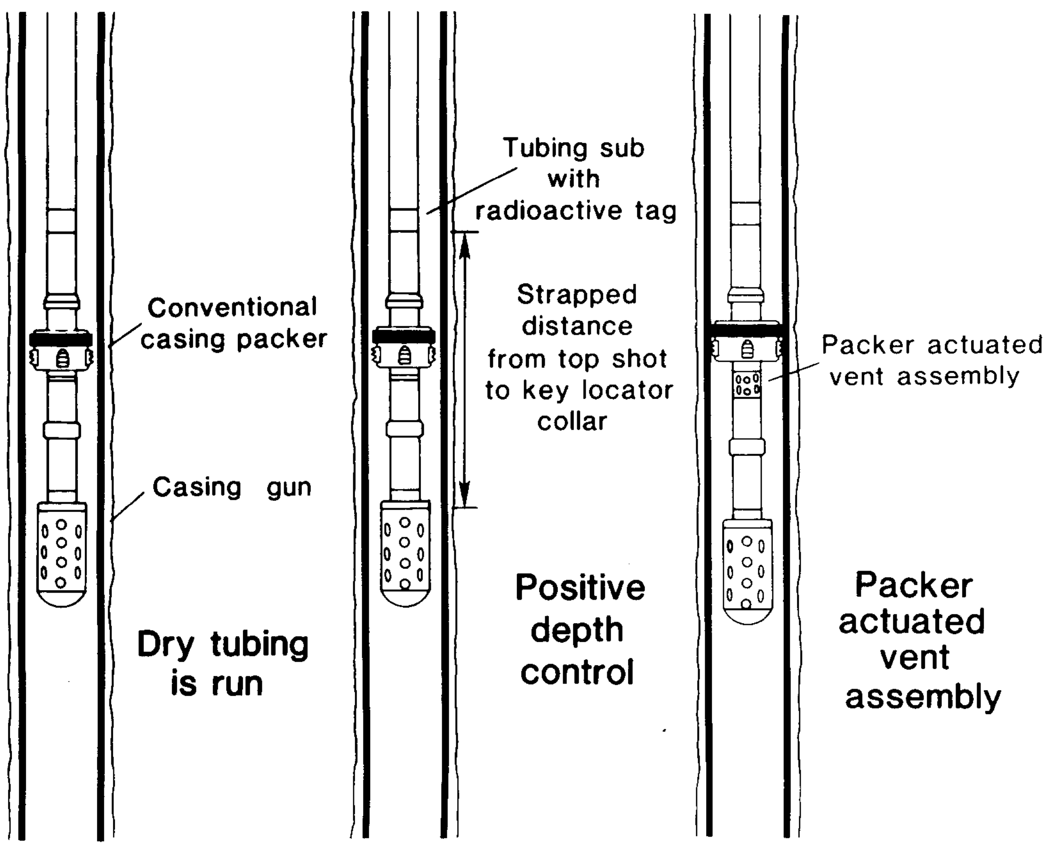

FIGURE 2—RUNNING AND SETTING EQUIPMENT IN PLACE

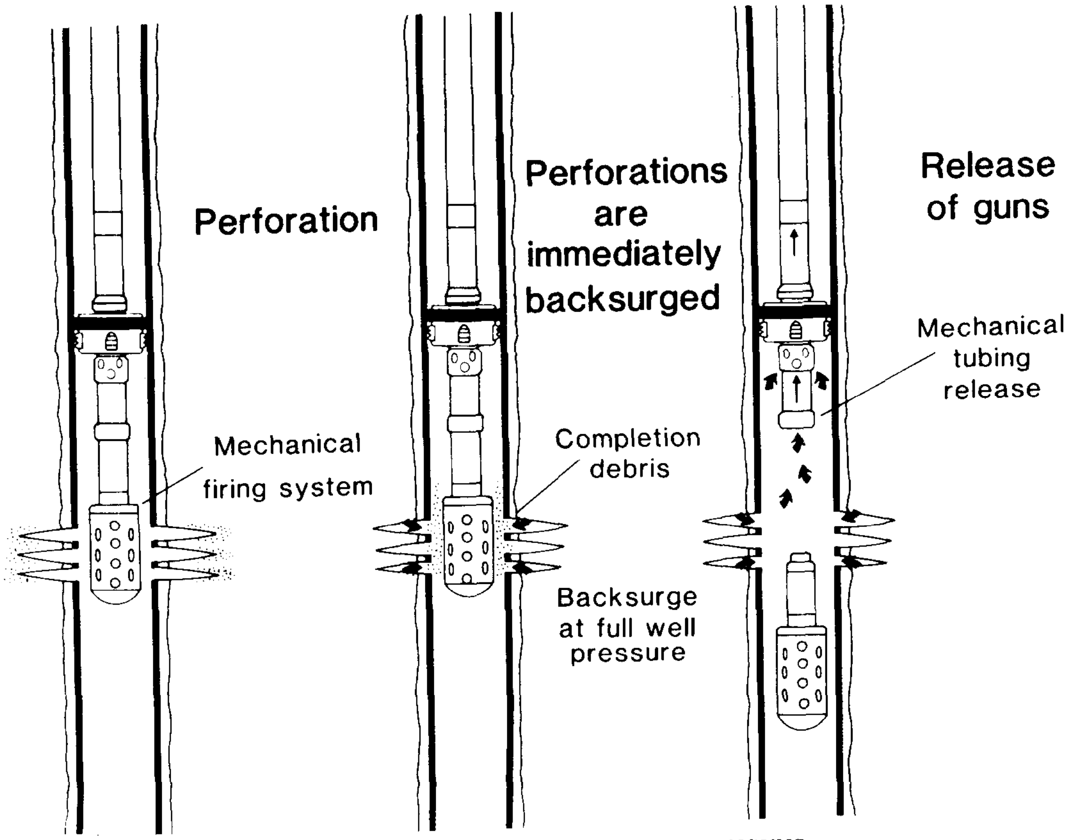

FIGURE 3—FIRING AND RELEASING VANNGUNS

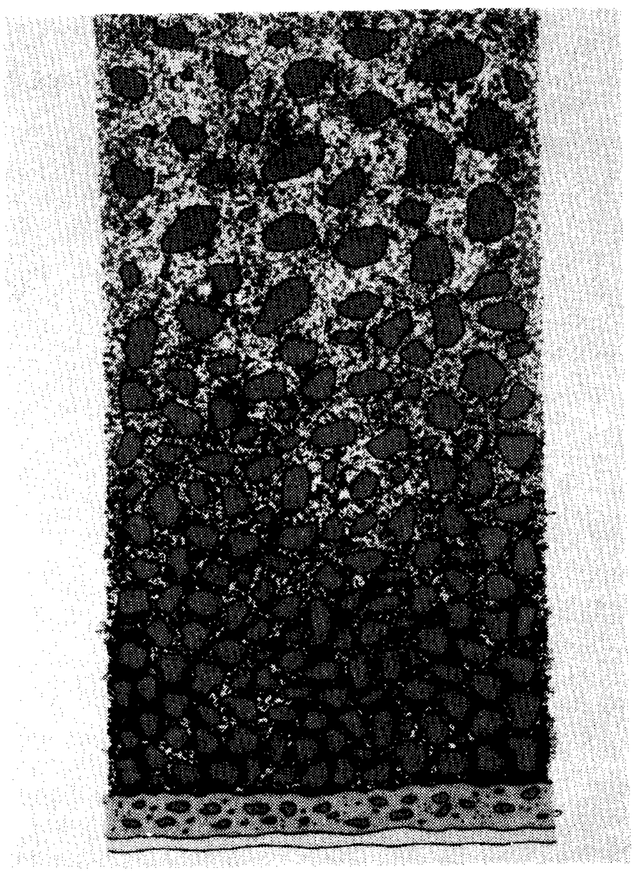

FIGURE 4—FORMATION DAMAGE

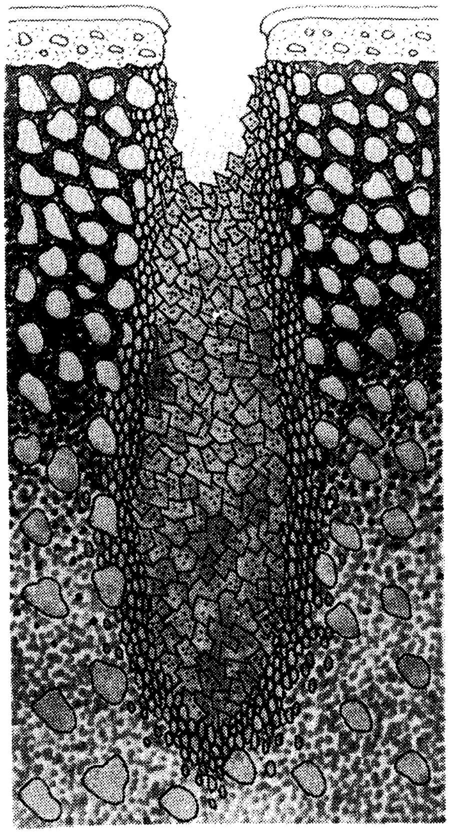

FIGURE 5—PERFORATION DAMAGE

Rocky Mountain Well With 4900 psi Toward the Wellbore
Completed By The Vannsystem

Washakee County, Wyoming (Dakota) — Case History # 607

Perforated Intervals: 11,304'-11,316' — 14% Porosity Zone

2 Shots Per Foot — 4900 psi Differental Towards the Wellbore

After Perforating the Well Had Gas at the Surface in Seven Minutes

Tested at: 1.26 MMCFD and 199 BOPD on 16/64-Inch Choke

FTP: 800 psi — Stimulation Was Not Required

FIGURE 7—CASE HISTORY, WYOMING

Vannsystem Completion/ Tubing Conveyed

Live Oak County, Texas
Upper Wilcox, Slick
Ø = 18%
Sw = 33%
3 3/8" HSC - 4JSF -120° Phaze
2085 psi differential

AOF = 24.200 MMCFGD

Jan. 1, 1979
FTP 1820 psi
1.065 MMCFGD

Well is not rate sensitive

FIGURE 6—CASE HISTORY, SOUTH TEXAS

VANNSYSTEM COMPLETION
Case History No. 3005

PROBLEM: OPERATOR WANTED TO KEEP FLUID OFF OF FORMATION TO PROTECT FROM POSSIBLE DAMAGE AND GIVE ZONE EVERY POSSIBLE CHANCE TO PRODUCE NATURALLY

WELL NAME: #2

FIELD: SOUTH BALKO

LOCATION: BEAVER COUNTY OKLAHOMA

FORMATION: CHESTER

DEPTH: 8500'

INTERVAL: 36' 4-JSF

DIFFERENTIAL: MAXIMUM

RESULTS: NATURAL COMPLETION
GAS TO SURFACE 4 MINUTES FROM TIME GUNS FIRED

1 HOUR AFTER GUNS FIRED
2250 PSI ON 20 64 CHOKE
PRODUCING 6.5 MMCFGD
30 MIN SITP - 2450 PSI

FIGURE 8—CASE HISTORY, OKLAHOMA

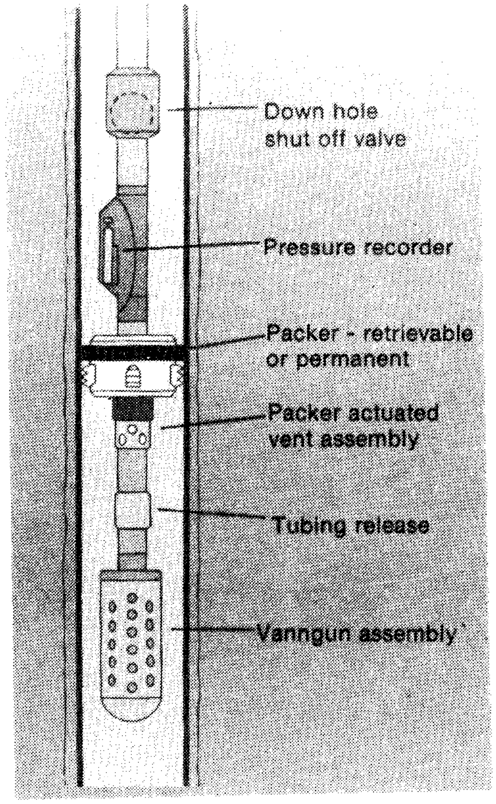

FIGURE 9—VANNSYSTEM FOR WELL TESTING

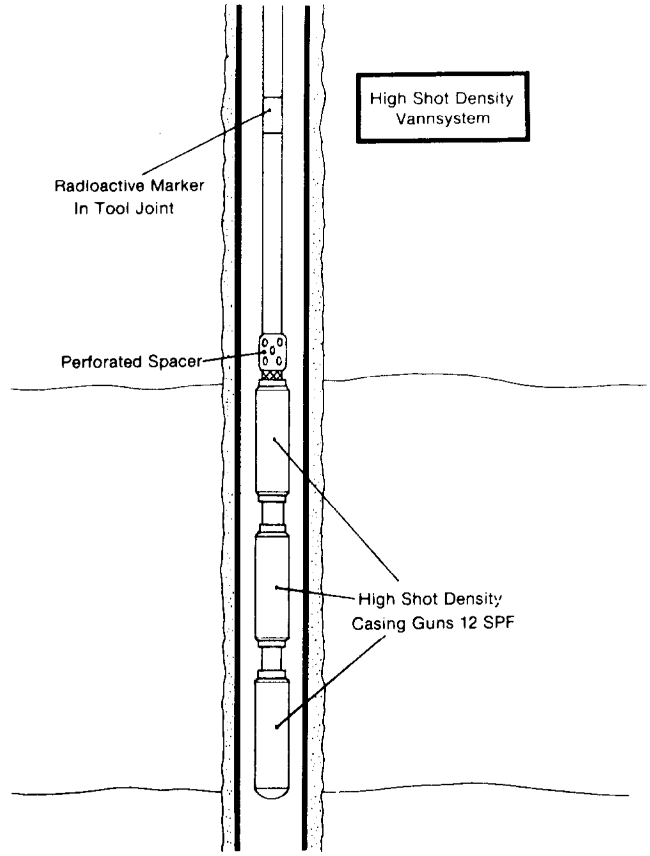

FIGURE 11—SPECIAL HIGH SHOT DENSITY HOOK-UP

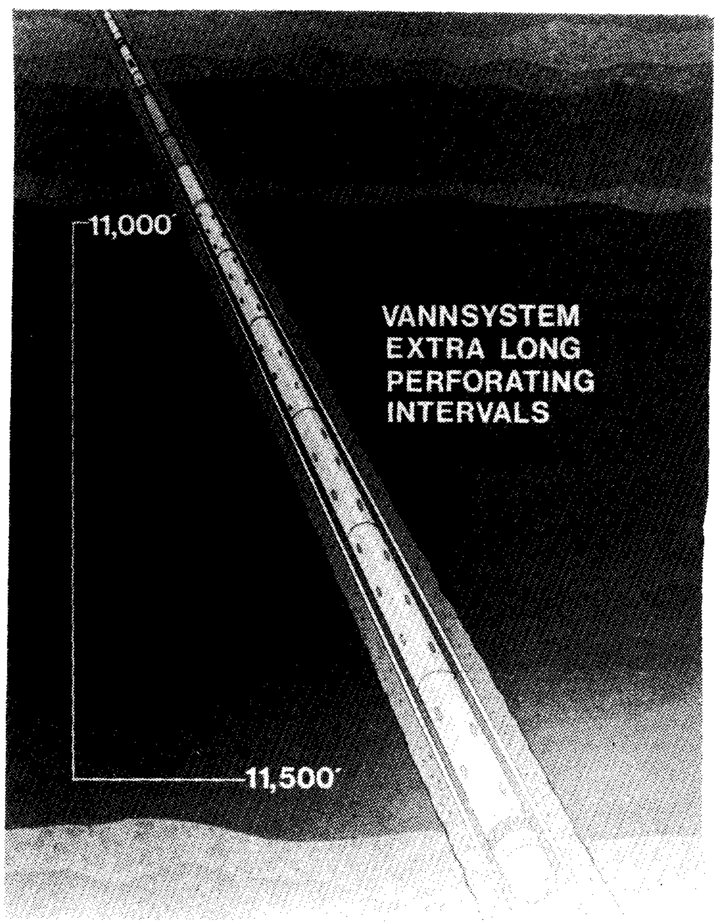

FIGURE 10—VANNSYSTEM - LONG INTERVALL ILLUSTRATION

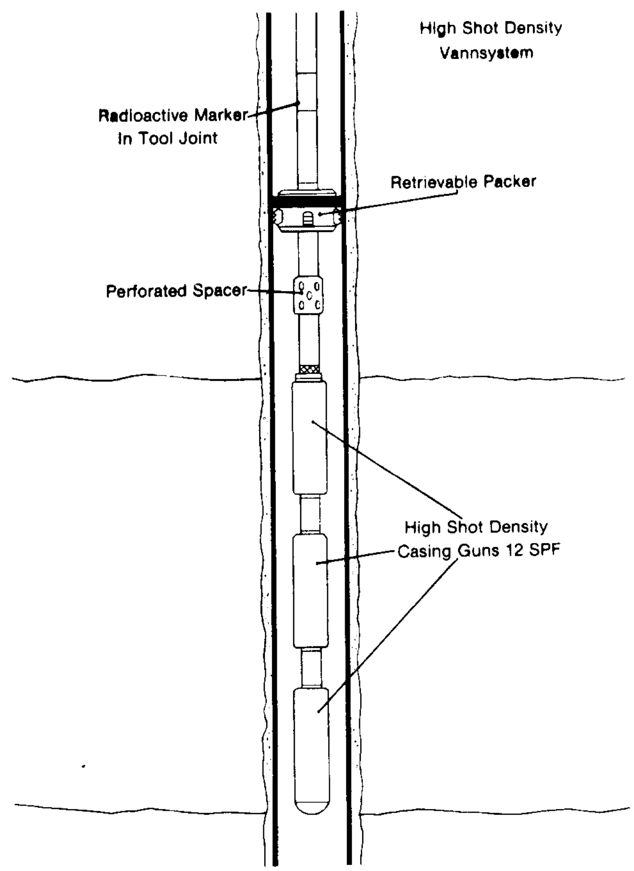

FIGURE 12—STANDARD HIGH SHOT DENSITY HOOK-UP

TUBING-CONVEYED GRAVEL PACKED COMPLETIONS
SOUTH TIMBALIER FIELD

	WELL NO. A	WELL NO. B
SAND NAME	TEXT 25 NO. 1	TEXT 25 NO. 1
TYPE COMPLETION	SINGLE, 4-1/2" TUBING	SINGLE, 4-1/2" TUBING
TYPE SAND CONTROL	GRAVEL PACKED	GRAVEL PACKED
TYPE GUN	6" TUBING-CONVEYED	6" TUBING-CONVEYED
SPF	12	12
PERF HOLE SIZE	.75" DIAM	.75" DIAM
PRESS DIFFERENTIAL	370 PSI UNDERBALANCED	500 PSI UNDERBALANCED
PERFORATED INTERVAL	116'	94'
SIBHP	1688 PSI	1720 PSI
GAS TEST RATE	23.1 MMCFD	20.0 MMCFD
FBHP	1613 PSI	1550 PSI
ΔP ACROSS COMPLETION	75 PSI	170 PSI
FTP	1328 PSI	1200 PSI
SPECIFIC PRODUCTIVITY INDEX	0.81 CFD/PSI²/FT	0.38 CFD/PSI²/FT
RESERVOIR CHARACTERISTICS		
DEPTH	6261' SS	6263' SS
TEMPERATURE	138° F	143° F
GEOLOGIC AGE	PLIOCENE	PLIOCENE

FIGURE 13—CASE HISTORY, HIGH SHOT DENSITY

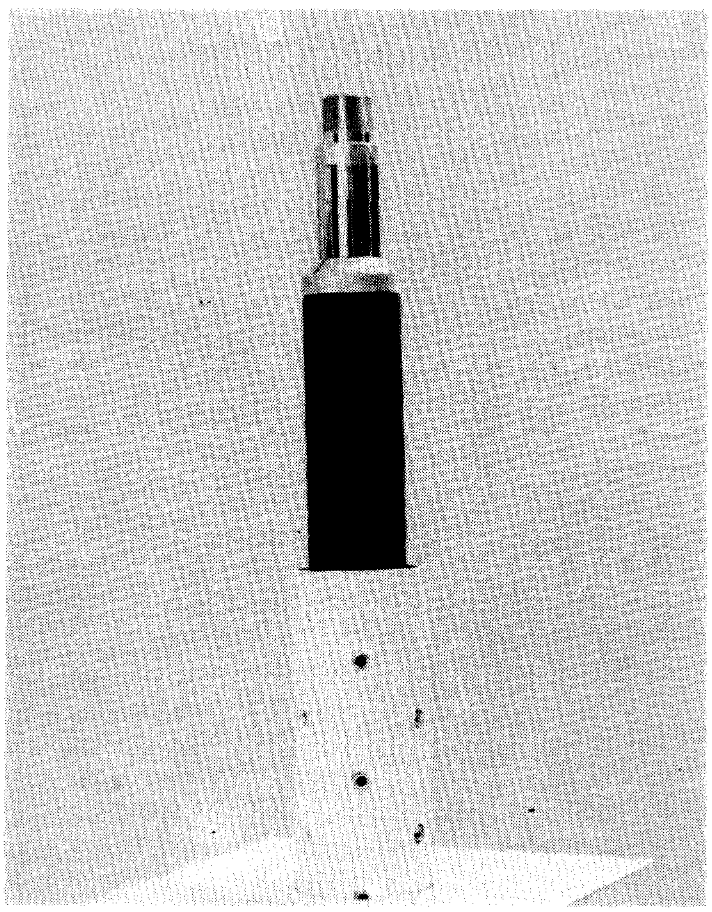

FIGURE 14—SHOT PATTERN, 12 SHOTS PER FOOT