SPE
Society of Petroleum Engineers

SPE 23639

Slim Hole Multiple Radials Drilled with Coiled Tubing

W. Dickinson* and R. Dickinson, Petrolphysics, Inc., A. Herrera, Corpoven, S.A.,
H. Dykstra* and J. Nees, Independent Consultants

* SPE Members

This paper was presented at the Second Latin American Petroleum Engineering Conference, II LAPEC, of the Society of Petroleum Engineers held in Caracas, Venezuela, March 8-11, 1992

Abstract

Two methods of combining water jet drilling and coiled tubing, the Ultrashort Radius Radial System (URRS) and the Quick Radial System (QRS), are described. Both provide multiple horizontal radials on a single horizon from a single vertical wellbore to penetrate near wellbore damage. The URRS requires section milling of the casing and underreaming of a cavity. The QRS penetrates the casing with abrasives. Typical field production results with both light and heavy oil are discussed.

I. Introduction

Oil well drilling and completion both have evolved through three generations of technology. The evolution of a fourth generation of technology is at hand. The first generation involved near surface production with little completion technology. The second involved drilling to modest depths with the successive development of explosive hole enlargement, acidizing and perforation. The third generation involved deep and directional drilling with sophisticated fracturing.

All of these technologies extended the effective wellbore diameter and markedly improved the well life and effectiveness by providing a better oil pathway from the formation to the wellbore.

Many oil provinces, particularly those which have been heavily drilled and have pressure depleted or damaged reservoirs, are entering a fourth generation of applied technology. This fourth generation of technology in part includes horizontal drilling and extended completion. This paper discusses two closely related horizontal drilling and extended completion technologies which combine water jet drilling, coiled tubing, and real-time trajectory control to provide multiple radial extended completions.

II. Water Jet Radial Drilling with Coiled Tubing

The concept and theory of water jet radial drilling and completion with a coiled tubing drillstring are described in many previous papers such as References 1 and 2.

References and illustrations at end of paper.

Two of the systems, the Ultrashort Radius Radial System (URRS) and the Quick Radial System (QRS) are compared in Figure 1. On the left side of the figure is the URRS. That system makes a vertical to horizontal turn in a 30 cm (one foot) radius. On the right side of Figure 1 is shown the QRS. The QRS can function as a short radius, 6 to 15 m (20 to 50 ft), a medium radius, 30 to 90 m (100 to 300 ft) or even a long radius, 300 to 1500 m (1000 to 5000 ft) systems.

Water jet drilling does not depend upon rotation of a bit. Thus, the combination of a water jet drill with coiled tubing does not subject that coiled tubing string to torque loading. Both the URRS and QRS systems can function with coiled tubing strings of both smaller diameter, 32 mm (1-1/4 inch), or larger diameter, 38 to 89 mm (1-1/2 to 3-1/2 inch). Of course, in most applications where on-road mobility of a coiled tubing unit is required, near term field service will probably be limited to units employing 32 to 38 mm (1-1/4 to 1-1/2 inch) diameter coiled tubing.

A. The Ultrashort Radius Radial System (URRS)

The hardware of the URRS is shown in Figures 2 to 13 which are reproduced from Reference No. 1. This hardware is capable of accurately placing multiple 30 to 60 m (100 to 200 ft) long radials, either in one reservoir stratum or in several reservoir layers.

1. Whipstock: ultrashort radius whipstocks erected into a 61 cm (24 inch) underreamed zone. Suitable underreaming is provided by mechanical or water jet tools (Figure 3).

2. Drillstring: Drilling with 32 mm (1-1/4 inch) coiled tubing in a long continuous joint propelled into the earth by hydraulic force.

3. Jet Drilling: Medium pressure, conical water jet drilling at 34.5 to 69 MPa (5,000 to 10,000 psi)(Figures 4 and 5).

4. Control While Drilling: Control of the drill trajectory to provide Control While Drilling (CWD)(Figure 6). The forces applied by the CWD system are shown in Figure 7. Rate of penetration is controlled by an independent hydraulic Motion Controller (Figure 3).

5. Positional Surveying: Accurate positional surveying of horizontal drillstring trajectory by means of flexible wireline tools (Figure 8).

6. Cutoff and Perforation: Electrochemical downhole cutoff and perforation of the 32 mm (1-1/4 inch) tube.

7. Gravel Packing: Horizontal, bi-directional gravel packing which is believed to be 100%-fill based on full-scale testing (Figures 9-11).

8. Slotted Liner: Flexible Sand Barrier with re-entrant helical slots for sand control (Figure 12).

9. Gravity Drainage: Gravity reservoir drainage with vertical pumping for low pressure reservoirs (Figure 11).

DATA

Five typical wells in which the Ultrashort Radius Radial System radials have been placed have been discussed in detail in the recent literature (Ref. 1). Each of these five typical wells demonstrates the applicability of the URRS to a variety of reservoir conditions. The examples include one heavy oil well in California, two light oil wells in Wyoming, and two light oil wells in Louisiana. Additional typical heavy oil results with thermal EOR have been presented for two heavy oil wells employing the URRS (one huff and puff, the other steamflood). These data are presented in SPE Drilling Engineering, September, 1989 (Ref. 2).

B. The Quick Radial System (QRS)

The Quick Radial System is so named because it is designed to do the job of multiple horizontal water jet drilling much faster and at a lesser cost (Figure 13).

As shown in Figure 13, the radials penetrate the casing by abrasive jetting. Hence, the steps of section milling and underreaming required for the URRS are not required for the QRS.

The QRS downhole components are shown in Figure 14. The five steps in the QRS process are as follows:

(1) Set a packer supporting the whipstock.

(2) Lower a coiled tubing string having a casing-penetrating drillhead capable of handling an abrasive slurry of frac sand. To avoid helical buckling with attendant high side wall friction, downhole assemblies that keep the coiled tubing in tension and effectively push the tubing from the bottom of the hole through the whipstock can be used.

(3) Move the abrasive drillhead through the whipstock to an appropriate position. An abrasive slurry is then pumped down the coiled tubing string with incremental movements of the drillhead. The slurry cuts an elliptical hole of about 5 cm (2 inches) horizontal width by 15 to 25 cm (6 to 10 inches) vertical length through which the drillhead will pass obliquely into the formation.

(4) Remove the coiled tubing string and casing-penetrating drillhead from the well. The casing-penetrating drillhead is replaced with a formation-penetration drillhead. This formation drillhead is usually a Conical Jet as previously discussed and shown in Figures 4 and 5. The formation-cutting assembly embodies a Control While Drilling (CWD) capability (Figure 6) which is operated via a wireline from the surface. Directional information for both location and trajectory control are transmitted up or down from the surface, as with the URRS.

(5) Drill through the formation with the drillstring curving out into the formation. At about the midway (45 degree) vertical deviation, the CWD system is activated and the drill begins to flatten its trajectory under the action of the side thruster jets previously described for the URRS and shown in Figures 6 and 7. The result is a progressive straightening within the formation to achieve a generally horizontal or other specified trajectory. Thereafter the trajectory is controlled as with the URRS in Figures 5, 6, and 7. After the formation drilling phase, the same steps of logging and completion with Flexible Sand Barrier (FSB) or gravel packing can be accomplished as shown in Figures 8 to 12 for the URRS.

With the QRS individual connection of the radials can be made back to the surface. This can be done by making a nonretrievable whipstock wherein more than one radial may be placed downhole and each is connected back to the surface.

In all, the QRS offers a faster method to place multiple radials at lower cost.

III. Results

In several previously referenced papers from which much of the URRS material herein was taken, typical field results with multiple radials were discussed. As more field data over longer production periods has become available, it is of interest that the production increases from multiple 30 to 60 m (100 to 200 ft) radials have generally exceeded the predicted increases for those lengths of multiple radials set forth in a paper by Herman Dykstra (Ref. 4) from which Table 1 is taken. As shown in Table 1 based upon the analysis set forth in References 3 and 4, with three typical radial lengths, three radials of 30 m (100 ft) length in a single layer in a 6 m (20 ft) reservoir should yield about three times greater production. But the field results usually substantially exceed this calculated improvement in production and approach results for 61 m (200 ft) or greater lengths.

It is believed that the probable reasons for greater than predicted enhanced production with multiple radials are threefold.

First, the multiple radials are penetrating near wellbore damage from drilling fluid infiltration. In effect, they are long perforations with no tunnel damage.

Second, the multiple radials are penetrating the next outward element of near wellbore damage caused by infiltration and plugging of the near wellbore zone during production.

Third, the application of multiple radials may be accessing heretofore nonmobile oil which has not been producible because of reservoir heterogeneity and K_v/K_h limitations.

IV. Interpretation

The field data from multiple radials continues to be encouraging in four ways:

(1) Increased production by generally two to ten times as compared to offset vertical wells with both light and heavy oil (a multiplier of four times greater production is typical).

(2) Decreased water/oil ratio by as much as ten times in strong water drive reservoirs.

(3) A strong flattening, i.e., decrease in slope of the production decline curve over the periods measured to date of up to two to three years in several geographically diverse reservoirs as compared to offset wells.

(4) An indication that greater producible reserves may be achieved with the combination of the preceding three factors.

V. Conclusions

A. Two different systems of placement of multiple extended completion radials using water jet drilling with a coiled tubing drillstring have been developed - the Ultrashort Radius Radial System (URRS) and the Quick Radial System (QRS).

B. In the QRS, the coiled tubing drillstring enters the formation by abrasively penetrating the casing so that no section milling nor underreaming of a downhole cavity is required.

C. In both systems, the trajectory of the radials can be controlled or straightened by side thruster water jets and that trajectory is indicated while drilling.

D. In the QRS, the multiple radials can be completed back to the surface.

E. With the shorter time required for well preparation, the Quick Radial System (QRS) should provide substantially lower cost multiple radials.

References

1. Dickinson, W, R.W. Dickinson, J. Nees, E. Dickinson, and H. Dykstra: "Field Production Results With The Ultrashort Radius Radial System in Unconsolidated Sandstone Formations", Proceedings of the 5th UNITAR International Conference on Heavy Crude and Tar Sands, Caracas, Venezuela, August 4-9, 1991, Volume II, pp. 307-326.

2. Dickinson, W., R.R. Anderson, and R.W. Dickinson: "The Ultrashort-Radius Radial System", SPE Drilling Engineering, September, 1989, pp. 247-254.

3. Dykstra, H. and W. Dickinson: "Oil Recovery by Gravity Drainage Into Horizontal Wells Compared With Recovery From Vertical Wells", SPE Paper No. 19827, presented at the 64th Annual Meeting of the Society of Petroleum Engineers, San Antonio, TX, October 8-11, 1989.

4. Dykstra, Herman: "Productivity of Radials or Horizontal Wells as Affected by Their Length and Number", privately printed monograph, October 19, 1988.

Bibliography

1. Dickinson, W, R.W. Dickinson, J. Nees, E. Dickinson, and H. Dykstra: "Field Production Results With The Ultrashort Radius Radial System in Unconsolidated Sandstone Formations", Proceedings of the 5th UNITAR International Conference on Heavy Crude and Tar Sands, Caracas, Venezuela, August 4-9, 1991, Volume II, pp. 307-326.

2. Dickinson, W., R.R. Anderson, and R.W. Dickinson: "The Ultrashort-Radius Radial System", SPE Drilling Engineering, September, 1989, pp. 247-254.

3. Toma, P., V. Reitman, and W. Dickinson: "Long and Ultrashort Turning Radius of Horizontal Wells: Predictions of Future Production Based on Today's Experience", presented at the World Petroleum Congress, Buenos Aires, Argentina, October 20-25, 1991.

4. Dykstra, H. and W. Dickinson: "Oil Recovery by Gravity Drainage Into Horizontal Wells Compared With Recovery From Vertical Wells", SPE Paper No. 19827, presented at the 64th Annual Meeting of the Society of Petroleum Engineers, San Antonio, TX, October 8-11, 1989.

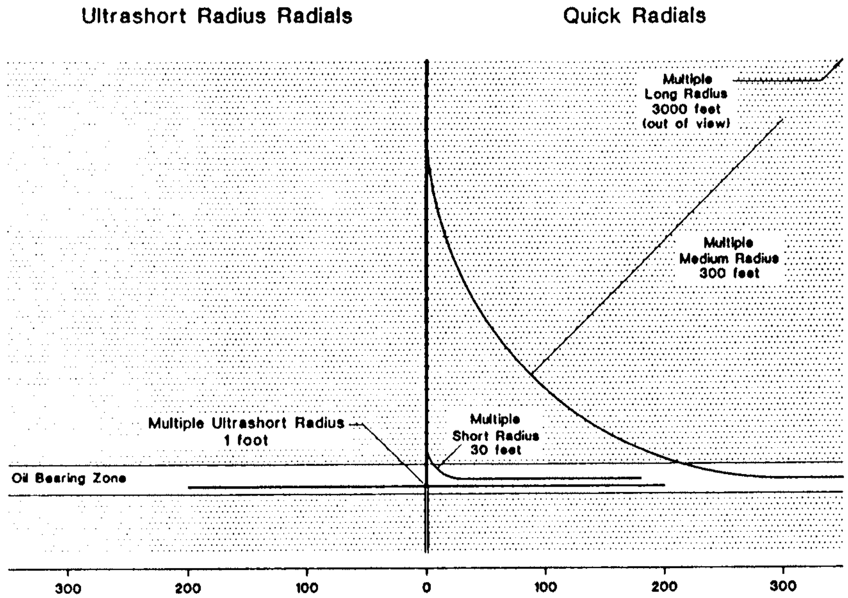


Figure 1

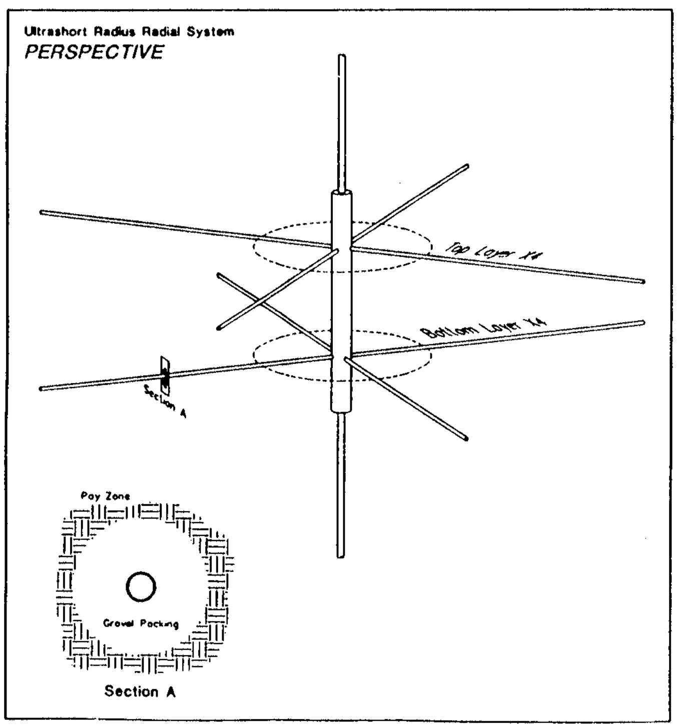


Figure 2

RATIO OF PRODUCTIVITY INDEX OF MULTIPLE HORIZONTAL RADIALS TO THAT OF A VERTICAL WELL

Radial Length in Feet	Formation Thickness in Feet	Number of Layers	Index Ratio One Radial per Layer	Index Ratio Two Radials per Layer	Index Ratio Three Radials per Layer	Index Ratio Four Radials per Layer
100	20	1	2.11	2.86	3.03	3.14
200	20	1	2.86	4.16	4.43	4.60
400	20	1	4.16	7.19	7.90	8.38

ULTRASHORT RADIUS RADIAL SYSTEM

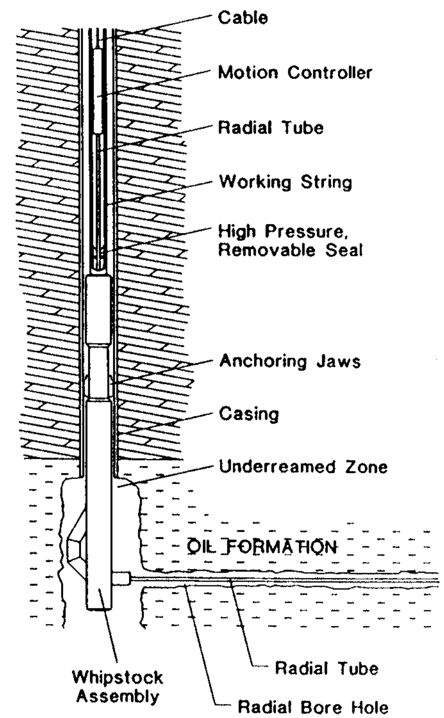


Figure 3

A CONICAL JET NOZZLE

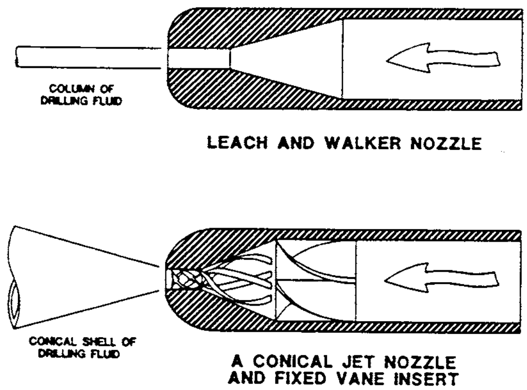


Figure 4

VERTICAL DEVIATION CONTROL WHILE DRILLING

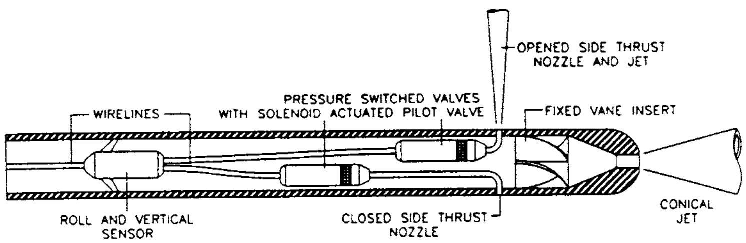


Figure 6

FORCES APPLIED BY THE CONTROL SYSTEM

PETROLPHYSICS ULTRASHORT RADIUS RADIAL SYSTEM INCLINOMETER SURVEY

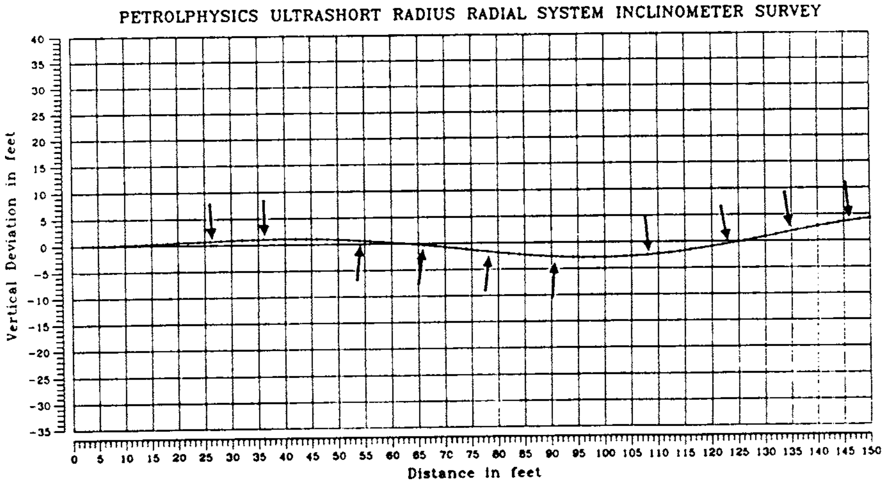
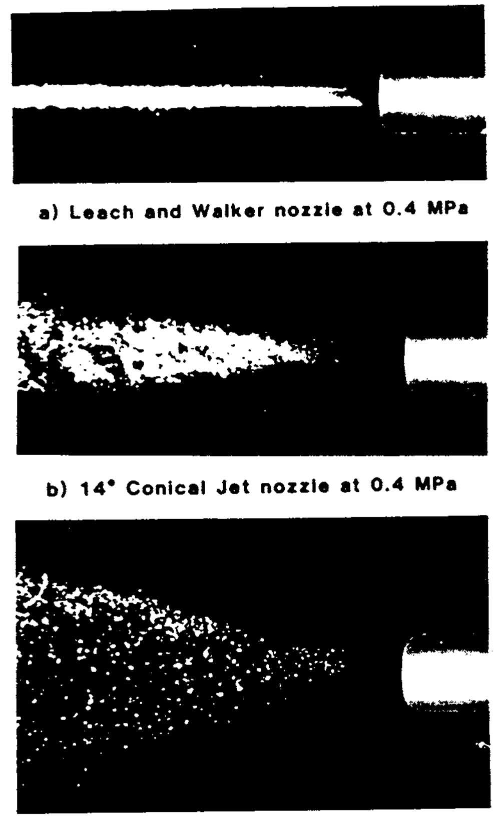


Figure 7



a) Leach and Walker nozzle at 0.4 MPa

b) 14° Conical Jet nozzle at 0.4 MPa

c) 30° Conical Jet nozzle at 0.4 MPa

Figure 5

Flexible Radius of Curvature Tool

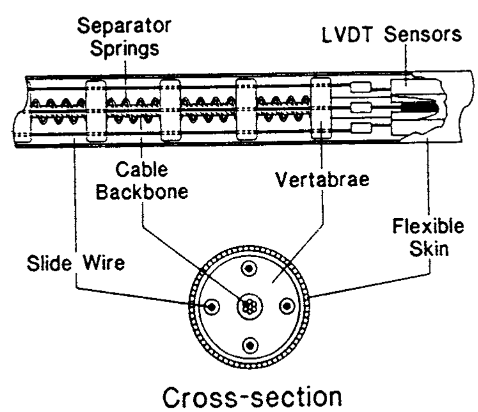


Figure 8

GRAVEL MOVEMENT IN FIRST LIFT

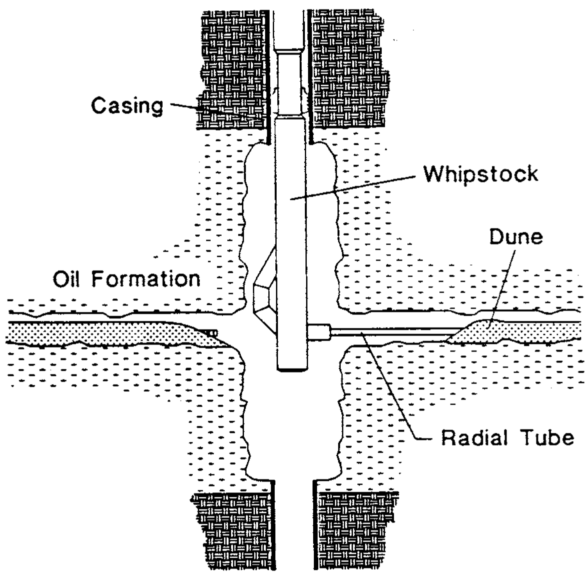


Figure 9

INTERIM GRAVEL MOVEMENT IN SECOND LIFT

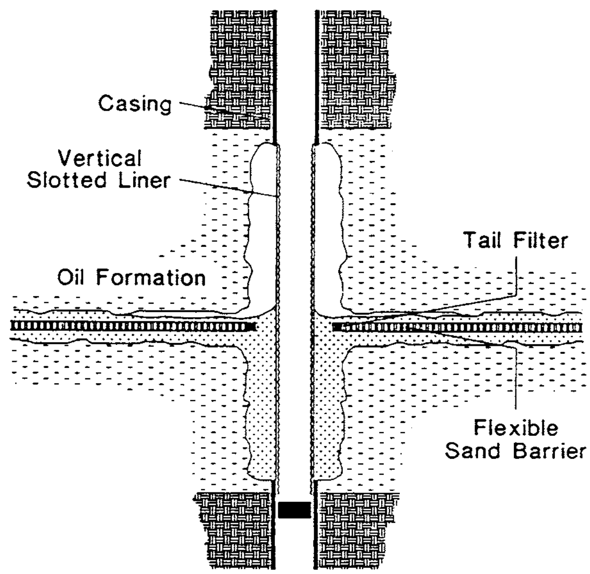


Figure 10

COMPLETED ULTRASHORT RADIUS RADIAL SYSTEM WITH GRAVITY DRAINAGE

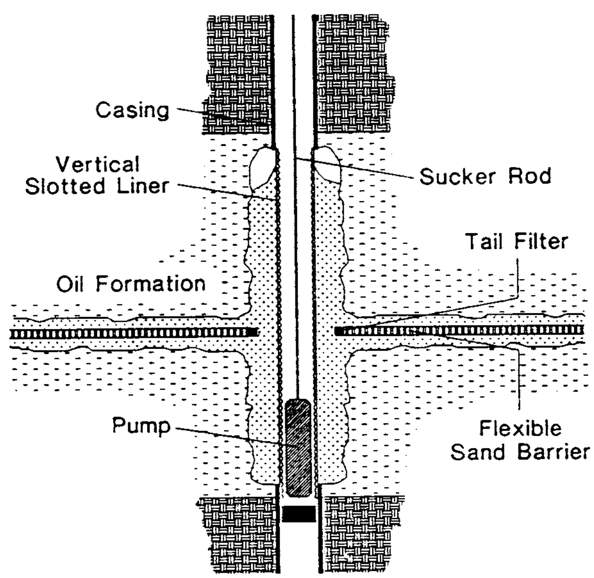


Figure 11

FLEXIBLE SAND BARRIER

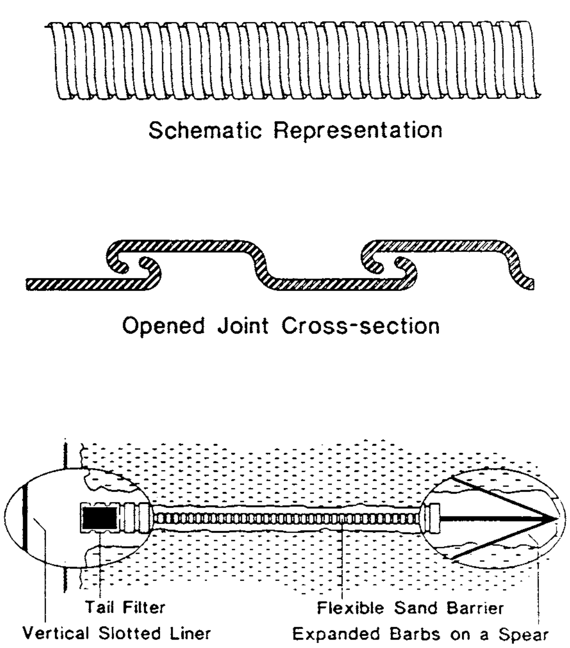


Figure 12

QUICK RADIAL SYSTEM

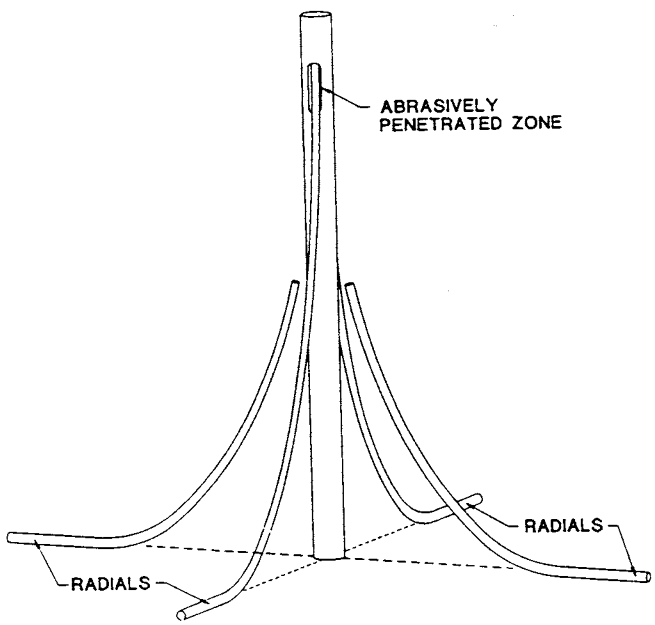


Figure 13

QUICK RADIAL SYSTEM

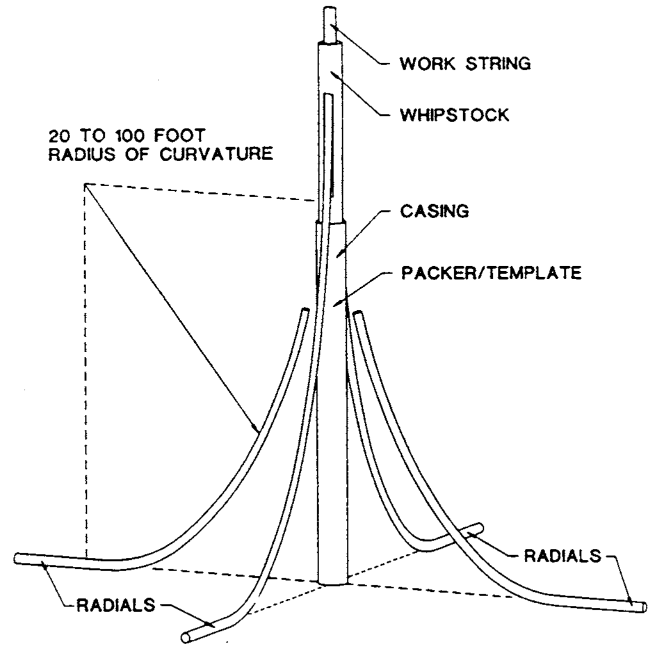


Figure 14