SPE 26348

Coiled-Tubing Radials Placed by Water-Jet Drilling: Field Results, Theory, and Practice

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This paper was prepared for presentation at the 68th Annual Technical Conference and Exhibition of the Society of Petroleum Engineers held in Houston, Texas, 3-6 October 1993.

I. Introduction

The URRS makes multiple 25 to 150 ft (8 to 46 m) radials in one or more layers. The range of stable production enhancement with multiple radials in both light and heavy oil wells in various formations varies from a two times (200%) to as much as a ten times (1,000%) improvement depending on reservoir and wellbore conditions. The average production improvement is two times to four times (200% to 400%). The comparison is made with respect to either (a) the production in a well after radial placement compared to the production prior to radial placement or (b) the production in a new well with radials compared to similar offset vertical wells.

This paper examines

(a) the value of multiple radials in penetrating skin or near wellbore damage (**Figure 1**);

(b) the calculated magnitude of oil production improvement by penetrating near wellbore damage; and

(c) typical light oil field results involving stable production in a new well with radials, and a reentered well with radials.

II. Theory and Definition

Formation damage usually refers to reduction in permeability of a formation around a wellbore caused by extraneous solid particles in the interstices of formation sand, rock, particles, and asphalt. The damage is evaluated by means of a skin factor which can be calculated from an analysis of pressure buildup or falloff data.

The skin factor determined in this way may include factors other than simple formation damage. The buildup test yields a skin factor that includes the effect of any restriction to flow into a wellbore. Besides permeability reduction, other factors such as partial penetration and partial well completions (not perforating the full interval) can also restrict the flow. Thus, in order to properly design a stimulation job such as acidizing, fracing, or drilling horizontal radials, it is necessary to determine the contribution of other factors to the total skin determined from a buildup analysis. These factors are discussed below.

References and illustrations at end of paper.

A. Skin Effect Causes

1. Formation Damage

The concept of a skin effect was developed by van Everdingen (**Ref. 1**). The idea of a skin is that formation near the wellbore has been affected out to a radius, r, such that its effective permeability may be lower (formation damage) or higher (from fracturing) than the permeability of the formation itself. The extra pressure effect for damage over a radius from r_w to r_d is called a skin effect, Δp_{skin}. This is illustrated in **Figure 2**.

The pressure drawdown without a skin effect (**Figure 2**) can be written as

$$\bar{p} - p'_{wf} = \frac{141.2 q\mu B \ln\left(\frac{r_{\bar{p}}}{r_w}\right)}{kh} \qquad \text{...(1)}$$

and with skin as

$$\bar{p} - p'_{wf} = \bar{p} - p_{wf} - \Delta p_{skin} \qquad \text{...(2)}$$

Using the form of Equation 1, the skin effect caused by the damaged zone is

$$\Delta p_{skin} = \frac{141.2 q\mu B}{kh} s_d \qquad \text{...(3)}$$

Combining the equations gives

$$\bar{p} - p_{wf} = \frac{141.2 q\mu B}{kh}\left[\ln\left(\frac{r_{\bar{p}}}{r_w}\right) + s_d\right] \qquad \text{...(4)}$$

An equation of the form of Equation 1 can be written for the pressure drop from r_d to r_w and a similar equation can be written for the pressure drop from $r_{\bar{p}}$ to r_d. The total pressure drop is their sum.

The resulting pressure drawdown, $\bar{p} - p_{wf}$, based on the two permeabilities in series and their respective radial distances can then be calculated from

$$\bar{p} - p_{wf} = \frac{141.2 q\mu B}{kh} \times \left[\ln\left(\frac{r_{\bar{p}}}{r_w}\right) + \left(\frac{k}{k_d - 1}\right)\ln\left(\frac{r_d}{r_w}\right)\right] \qquad \text{...(5)}$$

From this equation (**Figure 2**), we can express the skin effect resulting from formation damage s_d as

$$s_d = \left(\frac{k}{k_d - 1}\right)\ln\left(\frac{r_d}{r_w}\right) \qquad \text{...(6)}$$

This equation has three unknowns and in order to determine one of the terms it is necessary to know, or assume, the other two.

Another way of examining the effect of skin is by means of a flow efficiency. The flow efficiency, *FE*, is defined as the ratio of actual productivity index (PI) of a well to its ideal PI if there were no skin present (**Ref. 2**).

$$FE = \frac{J_{actual}}{J_{ideal}} \qquad \text{...(7)}$$

Since $J_{actual} = \frac{q}{(\bar{p} - p_{wf})}$ ...(8)

and $$J_{ideal} = \frac{q}{\bar{p} - p_{wf} - \Delta p_{skin}} \qquad \text{...(9)}$$

The flow efficiency can then be calculated from

$$FE = \frac{\bar{p} - p_{wf} - \Delta p_{skin}}{\bar{p} - p_{wf}} \qquad \text{...(10)}$$

By combining Equations 1 and 4, the flow efficiency can also be written as **(Ref. 3)**

$$FE = \frac{\ln\left(\frac{r_{\bar{p}}}{r_w}\right)}{\ln\left(\frac{r_{\bar{p}}}{r_w}\right) + s_d} \qquad \text{...(11)}$$

where s_d is now the total skin factor. This equation shows how *FE* is related to total skin.

For a well draining an area with a near circular closed outer boundary, the average pressure occurs at a distance from the wellbore of $0.47 r_e$ **(Ref. 2)**. By replacing $r_{\bar{p}}$ with $0.47 r_e$ and noting that ln 0.47=0.75, we see that Equation 11 reduces to

$$FE = \frac{\ln\left(\frac{r_e}{r_w}\right) - 0.75}{\ln\left(\frac{r_e}{r_w}\right) - 0.75 + s_d} \qquad \text{...(12)}$$

In this equation the skin, s_d, is the total skin which can be determined from buildup or falloff tests and includes all of the effects mentioned above.

B. Perforation Pseudo Skin Factors

The most common way of completing a well after it is drilled, is to cement casing in the wellbore and to jet or gun perforate through the casing and the surrounding cement sheath between the casing and the formation face. With careful design, the perforations are expected to penetrate the formation to be produced. Since the holes represent a limited area for flow into the wellbore compared to an open hole completion, they can be thought of as restricting the flow as it converges into the wellbore. On the other hand, if the holes penetrate a considerable distance into the formation, they can be thought of as a whole series of lateral drainholes or short radials and as such can allow a flow efficiency that is greater than 1.0.

The flow convergence results in a pseudo skin factor that was studied by means of electrolytic models by McDowell and Muskat (**Ref. 4**) and by Howard and Watson (**Ref. 5**). A later study was presented by Harris (**Ref. 3**) who solved the equations describing the idealized system by means of numerical simulation on a computer. Harris presented his results in a series of charts showing pseudo skin factor as a function of five variables: (1) cement sheath radius, r_W; (2) perforation diameter, d; (3) penetration beyond the cement sheath, a; (4) vertical perforation interval, h; and (5) the number of perforations per plane, m. He combined these variables into four dimensionless terms and plotted dimensionless skin effect as a function of dimensionless perforation penetration. He did not include the effect of a damage zone around the wellbore.

The results of Harris' work **(Ref. 3)** indicated that with four perforations per foot (twelve perforations per meter) in a plane, the productivity ratio or flow efficiency could exceed 1.0 for penetration depth greater than 7 inches (178 mm). Thus, it can be seen that with a proper perforating program that is designed to exceed 7 inches (178 mm) of penetration, the perforations should not result in a positive pseudo skin effect.

C. Partial Penetration Pseudo Skin Factors

In completing a well there may be a reason for not completing the well over the entire hydrocarbon interval. This is especially true when the producing zone underlies a gas cap, or overlies a water zone. Then only a portion of the zone will be open to flow such that there is convergence to flow into the wellbore.

The restriction to flow for partial penetrating wells was first solved by Muskat (**Ref. 6**) who also included the effect of anisotropy. Two additional references on this subject are by Brons and Marting (**Ref.** 7) and by Odeh (**Ref. 8**). The results by Brons and Marting cover only three situations: (1) an interval open only at the top of the formation, (2) open only in the center of the formation, or (3) uniformly divided into four intervals. On the other hand, the results by Odeh allow for placing the completed interval at any location within the zone. The results in all three references indicate that partial penetration always results in a positive pseudo skin factor. For partial completions, the skin factor can range up to as high as 50. In addition, as shown by Muskat **(Ref. 6)**, the effect of anisotropy (with vertical permeability being less than horizontal permeability) with partial penetration will result in a greater skin factor than for an isotropic formation.

D. Overcoming Flow Restriction Caused by Skin

As mentioned above, a stimulation job to overcome skin effect can be done by means of acidizing, fracing, or drilling of horizontal radials. The discussion to follow will be concerned with the use of radials to overcome a skin effect caused by damage around the wellbore.

In recent years many articles have been published on the drilling of horizontal wells, or radials, for improved production performance over that of vertical wells. Various publications (**Ref. 9, Ref. 10**) have presented equations and results of calculations that relate the productivity of horizontal wells to vertical wells. These references accounted for number, length, and placement of wells and for permeability anisotropy.

The results of calculations of the gains to be obtained with the drilling of horizontal wells or radials with and without formation damage are given in **Tables 1** and **2**. The equations in **Ref. 10** were used to calculate the ratios of productivity index of a horizontal well to that of a vertical well. A skin effect around the vertical well was not included in the application of the equations. **Table 1** shows the ratio with formation damage as a function of length, thickness, and permeability anisotropy for three different well spacings. **Table 2** shows the ratios without formation damage as a function of length and formation thickness for one to four horizontal wells at one to four levels. As can be seen, the largest gain is obtained with the smallest formation thickness.

To account for near wellbore damage, a study was made by Perrine (11) who used an electrolytic model to experimentally measure the relation between the productivity of a horizontal well and the productivity of a damaged vertical well. He determined the relation for a 100 ft (30 m) thick formation as a function of horizontal well length with two wells at each of three levels and for an 25 ft (8 m) formation with two wells at only one level. He used two radial widths of damage zone around the wellbore of 6-1/4 ft (1.9 m) and 12-1/2 ft (3.8 m) having a permeability reduction of 25.

Perrine **(Ref. 11)** related the productivity of a damaged well with drainholes to the productivity of an equivalent undamaged well without drainholes as shown in **Figures 2-4**.

If these results from **Figures 2-4** are divided by the flow efficiency (*FE*) for a damaged well without drainholes, we get the increase in productivity of a damaged well with drainholes. (The *FE* is defined by Equation 7 and can be calculated from Equation 11 incorporating the skin factor s_d from Equation 6.)

For his experimental work, Perrine used an equivalent wellbore diameter of 11-3/4 in. (298 mm) and an outer boundary radius of 500 ft (152 m). For a damaged zone of 6-1/4 ft (1.9 m) and 12-1/2 ft (3.8 m), Equation 6 gives skin factors of 62.9 and 78.7, respectively. Using these skin factors in Equation 11 results in *FE* values of 0.0894 and 0.0786. The resulting values of the ratio of productivity index of multiple horizontal radials to that of a vertical well with formation damage are shown in **Figures 3** and **4** for damage distances of 6-1/4 ft (1.9 m) and 12-1/2 ft (3.8 m) from the wellbore. The figures show the relation between production with radials, or horizontal wells, to the production of a damaged vertical well.

As can be seen, the gain in production rate for a 6-1/4 ft (1.9 m) damage zone, for two wells at a single level can range from 5.8 to 17.3 times that of a vertical well as the radial well length increases from 25 to 100 ft (8 to 30 m), and for two wells at each of three levels the gain ranges from 12.5 to 27.2. For a 12-1/2 ft (3.8 m) damage zone, the respective gains are from 5.7 to 19.7 for radials at one level and from 12.0 to 31.3 for three levels. The gain for an 25 ft (8 m) formation thickness is greater as depicted by the dashed lines in **Figures 3** and **4**.

The 6-1/4 and 12-1/2 ft (1.9 and 3.8 m) thicknesses used by Perrine (**Ref. 11**) for the damage zone is probably on the high side. Additional studies could be made to obtain relations similar to those shown by Perrine in his Figures 2 to 4 for thinner damage zones and for permeability ratios above and below the factor of 25 used by Perrine.

III. Applications of Equipment and Processes

A. Coiled Tubing Fluid (Water) Jet Drilling

During the past ten years, high performance radial water jet drilling systems have been developed to provide extended completion through near wellbore damage. All these jet radial systems use coiled tubing as a drillstring. The concept is to provide multidirectional, horizontal radials on the same or different levels. The radials make an ultrashort radius of turn of 12 in. (.31 m) from vertical to horizontal. The result is an array of radial boreholes which penetrate the near wellbore damage or skin and provide a set of undamaged radial conduits for gravity flow.

Two coiled tubing water (fluid) jet drilling systems are either in commercial use or under development for installation of horizontal or oblique radial drainholes. The first system, the Ultrashort Radius Radial System (URRS)(**Figure 5**)(**Ref. 12**), is being used commercially in U.S. and foreign fields. The URRS is based on conventional oil field equipment including a work over rig, section milling equipment, under reaming equipment, high pressure (8,000 to 10,000 lbs/in^2)(55.2 to 69.0 MPa) fracturing pumps and an adequately rated work string [4-1/2 in. (114 mm) screwed tubing with a section of smooth walled 3-1/2 in. (89 mm) motion controller tubing at the bottom]. The second system, the Quick Radial System (QRS)(**Figure 6**)(**Ref. 13**), which is under development requires installation and orientation of the whipstock but the remaining operations can be accomplished with a coiled tubing unit, a blender to mix abrasive fluids and medium pressure (3,500 to 5,000 lbs/in^2)(2.41 to 34.5 MPa) mud pumping equipment. Only the commercial URRS will be described herein.

B. Ultrashort Radius Radial System (URRS)

For a drillstring the URRS system utilizes a non-rotating 100 to 200 ft (30 to 61 m) length of 1-1/4 in. (32 mm) coiled tubing with a water (fluid) jet drillhead at its tip. As shown in **Figure** 7, the radial drainholes are drilled from a 24 in. (0.61 m) diameter by 10 ft (3.05 m) high window which has been section milled and underreamed in an existing wellbore. A whipstock to provide a 12 in. (.31 m) radius turn is anchored in the wellbore casing above the window. The whipstock is erected and held erect by pulling tension in the workstring at the surface. The short coiled tubing string and water (fluid) jet drillhead are connected back to the surface only by wireline. They are hydraulically propelled around the whipstock and into the formation by water pressure. The wireline connection to the surface provides power to the hydraulic directional control and brings back positional information in real-time. The rock drilling is accomplished by a special Conical Jet which creates a cone of water particles moving at 700 to 900 ft/sec (213 to 274 m/sec). These high velocity water particles cut a 2 to 4 in. (51 to 102 mm) diameter borehole in most rocks. The drilling rate is controlled by a downhole motion controller (braking) system. A schematic of the components of the URRS is shown in **Figure** 7.

C. Control While Drilling

A Control While Drilling System (**Ref. 14**), under continuing development for both the URRS and the QRS, allows the drillhead inclination to be monitored and adjusted by the operator while drilling. Adjustments to inclination are initiated from a control system computer located at the surface. Solenoid actuated pilot valves within the 1-1/4 in. (32 mm) coiled tubing drillstring direct high pressure drilling fluid to several side thruster jets that act perpendicular to the axis of the drill. These thruster jets are much the same as the small rocket thrusters used to maneuver rockets or satellites. With the control system, the operator can make adjustments to the drillhead inclination to follow a predetermined path in response to distance and inclinometer data available to the operator while drilling.

D. Inclination and Three Dimensional Survey of the Radial Drainhole

The radial drainhole can be surveyed by flexible wireline instruments. The simplest tool is a flexible wireline inclinometer which maps vertical trajectory in relation to the initiation point. The inclination angle along with wireline distance are measured for a series of points within the recently drilled drainhole. These data are converted into a plot of the vertical trajectory of the drainhole from its point of initiation.

A second more complicated flexible wireline tool (**Refs. 12 and 15**) is to provide a three dimensional (3-D) survey of the completed radial borehole.

E. Completions

Several completion options (**Refs. 12, 15, 16, and 18**) are available for the radial drainholes depending on client requirements: open hole, electrolytically perforated coiled tubing, flexible permeable casing (Flexible Sand Barrier), and horizontal gravel packing.

Because the exit pressure of the drillhead is essentially at formation pressure and because there is movement of the cuttings as a slurry back to the wellbore and thence to the surface, the formation around the radial borehole apparently is not damaged by the drilling process. This lack of damage has been measured experimentally in the laboratory. To further reduce formation damage, water-based fluids and no mud are used.

For most applications, the radial drainhole can be completed as an open hole or gravel packed. For open hole, the 1-1/4 in. (32 mm) coiled tubing drillstring is simply pulled back. For unconsolidated sands, horizontal gravel packing developed by Petrolphysics is applied.

For unconsolidated formations wherein Petrolphysics' gravel packing is applied, the drillhead is cut off electrochemically and the radial borehole is packed in two oppositely directed lifts of water and gravel slurry. The waterbased, low velocity slurry is pumped from the surface down the 4-1/2 in. (114 mm) workstring, into the 1-1/4 in. (32 mm) coiled tubing string and through it to the end of the drainhole. The slurry exits at the cutoff drillhead, and progressively backfills the radial borehole toward the existing wellbore. The first lift gravel packing fills 70-90% of the radial borehole.

Since the permeability is high in most formations requiring gravel packing, a second lift gravel pack is used for maximum fill. This second lift gravel pack is accomplished in conjunction with gravel packing of the existing vertical wellbore. Gravel slurry is deposited in the opposite direction from the first lift, i.e., progressively from the existing wellbore toward the end of the borehole and within the annulus of the borehole and coiled tubing drillstring. When the well is placed on production,. the result is a maximum gravel pack as shown in **Figure 8 (Ref. 16)**. Because of the ultrashort radius turn [12 in. (.31 m)], the produced oil can flow by gravity directly to a conventional pump.

IV. Presentation Of Data

Substantial gains appear to be had by overcoming skin effect by placement of multiple radials from a vertical or deviated wellbore. These effects are shown in **Figures 3** and **4** for a damaged reservoir considering only two radials per level at variously one, two, or three levels. Two damaged zone thicknesses 6-1/4 ft and 12-1/2 ft (1.9 m and 3.8 m) and two reservoir thicknesses 25 ft and 100 ft (8 m and 30 m) are considered. The ratio of Productivity Index with radials and without radials is plotted for radials of 0 to 100 ft (0 to 30 m) length.

The data is presented in tabular form in **Table 1**.

As a comparison, a similar analysis was made by one of the co-authors Dykstra (**Ref. 17**) for similar parameters but with no reservoir damage or skin. These data are respectively presented in **Figures 9, 10, and 11** and summarized in **Table 2**.

V. Interpretation of Data

The calculated effect of placing just two radials in one or more levels is shown in **Figure 3** for a 6-1/4 ft (1.9 m) damaged zone in a 25 ft (8 m) thick reservoir (one level) or 100 ft (30 m) thick reservoir (three levels). **Figure 4** shows the same type data calculated for a 12-1/2 ft (3.8 m) damaged zone. The results are shown in terms of the ratio of the Productivity Index (oil flow per unit pressure drop) for a damaged vertical well with two radials to that of a damaged vertical well with no radials. The calculated improvement in productivity index or in the related production rate from multiple short radials which penetrate near wellbore damage is 20 to 30 times (2,000% to 3,000%) more than a damaged vertical well. In comparison, the data for multiple radial placement in an undamaged well presented in **Figures 9, 10, and 11** show only two to three times (200% to 300%) improvement, i.e., 1/10 the effect of the damaged case for comparable radial length and well condition.

To provide an example of a typical field result based upon stable production data, **Figure 12** shows a radial application in Texaco wells from LaBarge Field in Wyoming. Three elements of stable production data are presented.

A. A reentry into a depleted well, J634, with three radials 54 to 70 ft (16 to 21 m) in length with production data before radial placement and after radial placement,

B. A new well, G634y, with three radials of 68 to 151 ft (21 to 46 m) in length, and

C. Several offset vertical wells without radials.

The data indicate a production increase of about two times in oil production and a halving of the rate of decline in the depleted well (J634). These data suggest that there may not have been severe wellbore damage in Well J634.

Production in a new well (G634y) with three radials is about four times that of offset vertical wells.

Other U.S. field data confirm this pattern of at least two and up to ten times production enhancement (200% to 1,000%) in oil wells with the application of multiple URRS radials depending in part upon the extent of near wellbore damage (**Ref. 19**). Average production enhancement is two to four times (200% to 400%).

VI. Conclusions

1. Field data associated with the application of multiple radials of 25 to 100 ft (8 to 30 m) in length shows improvement in productivity factors of two to four times (200% to 400%) in undamaged reservoirs in light and heavy oil. Rate of production decline is also reduced with multiple radials on a reentered well. The calculated production enhancement effects in wells without near wellbore damage are of the same order of magnitude.

2. If near wellbore damage (skin) is created by the infusion of drilling fluids or from migration of fines, the enhancement effects of multiple radials on production are calculated to be five to ten times (500% to 1,000%) larger than exists for an undamaged well for a skin of $k_{damaged}/k_{reservoir} = 1/25$.

3. These production enhancement effects are generally further enhanced in thinner reservoirs with radials [25 ft (8 m) as compared to 100 ft (30 m)].

4. Production enhancement with multiple layers of radials is relatively more effective in the thicker reservoirs.

Nomenclature

B = formation volume factor
J = productivity index
k = permeability, md
h = formation thickness, ft
$\bar{p}$ = average pressure in drainage volume
p = wellbore pressure with skin
p' = wellbore pressure without skin
q = flow rate, bpd
r = radius
s = skin
μ = viscosity, cp
Δp_{skin} = pressure drop across skin

Subscripts:

d = damage zone
e = outer boundary
w = wellbore
wf = flowing wellbore

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TABLE 1

Ratio Of Productivity Index Of A Vertical Well With Two Horizontal Radials To That Of Vertical Well With Formation Damage

Formation Thickness, ft	Damaged Zone, ft	Length of Radials, ft	Jh/Jv for Number of Layers of Radials			
			1	2	3	4
25	6.25	25	14.4			
		50	20.4			
		75	24.6			
		100	27.4			
25	12.50	25	13.7			
		50	21.8			
		75	27.4			
		100	31.7			
100	6.25	25	5.8	10.0	12.5	14.4
		50	10.3	15.8	18.9	20.4
		75	14.0	20.5	23.5	24.6
		100	17.3	24.5	27.2	27.4
100	12.50	25	5.7	9.5	12.0	13.7
		50	10.8	17.2	20.1	21.8
		75	15.5	22.9	26.2	27.4
		100	19.7	27.5	31.2	31.7

Note:
K/K-damaged = 25
R-wellbore = 0.49 feet
R-damaged = 6.25 feet
R-outter boundary = 500 feet

TABLE 2

Ratio Of Productivity Index Of A Vertical Well With Two Horizontal Radials To That Of A Vertical Well With No Formation Damage

Formation Thickness, Ft	Length of Radial, Ft	Jh/Jv for Number of Layers of Radials			
		1	2	3	4
10	50	2.30	2.38		
	100	3.03	3.10		
20	50	2.11	2.30	2.36	2.38
	100	2.86	3.03	3.08	3.10
40	50	1.74	2.00	2.24	2.30
	100	2.80	2.86	2.98	3.03

Note:
R-wellbore = 0.33 feet
R-outter boundary = 527 feet

Schematic of Damaged Zone

in Region of Wellbore

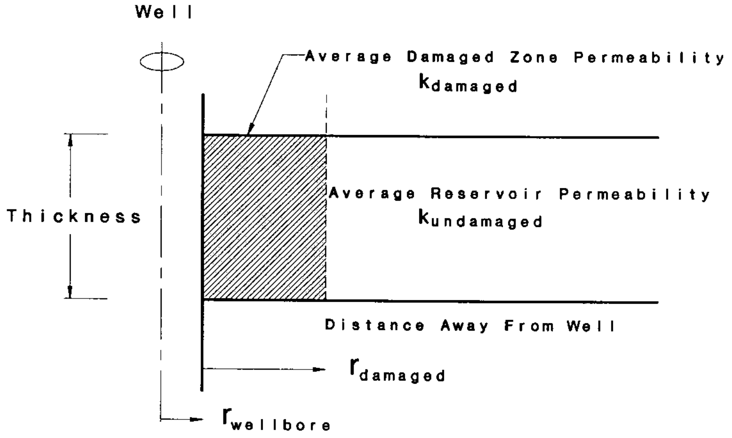


FIGURE 1

Schematic of Pressure-Log Radius Profile, Radial Flow with Damaged Zone

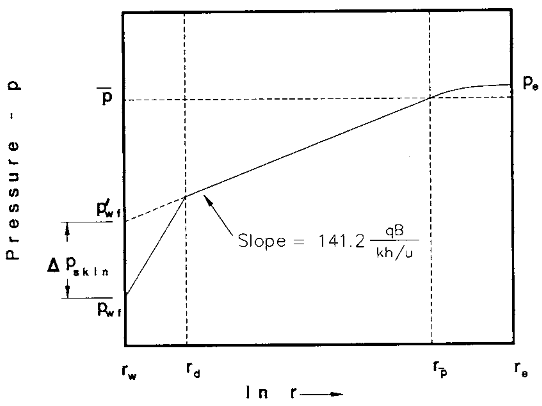


FIGURE 2

Ratio Of Productivity Index Of A Vertical Well with Two Horizontal Radials To That Of A Vertical Well With 6.25 Ft Damaged Zone

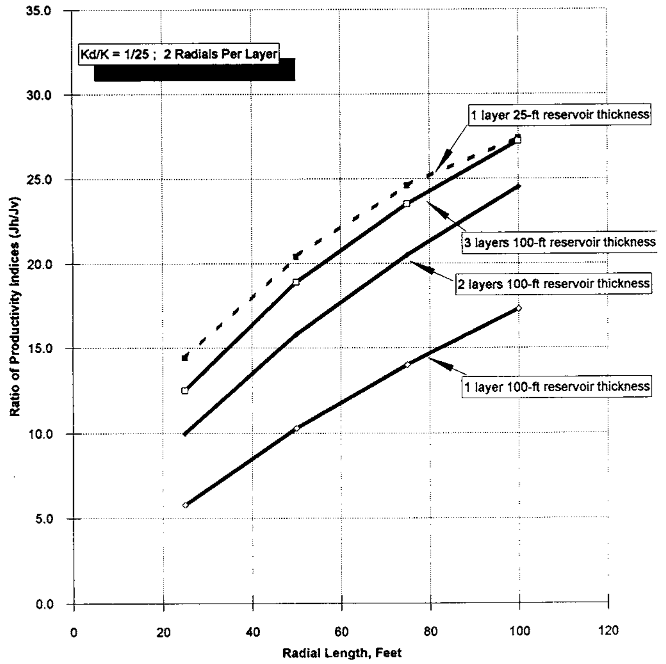


FIGURE 3

Ratio Of Productivity Index Of A Vertical Well of Two Horizontal Radials To That Of A Vertical Well With 12.5 Ft Damaged Zone

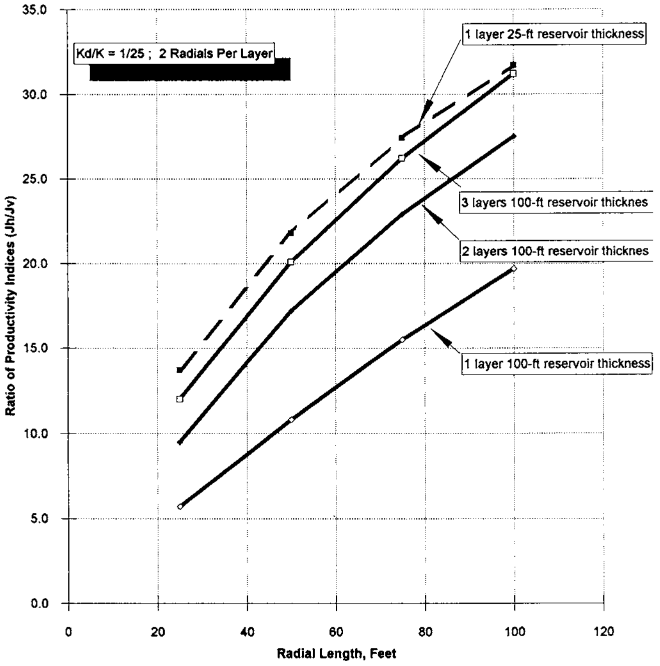


FIGURE 4

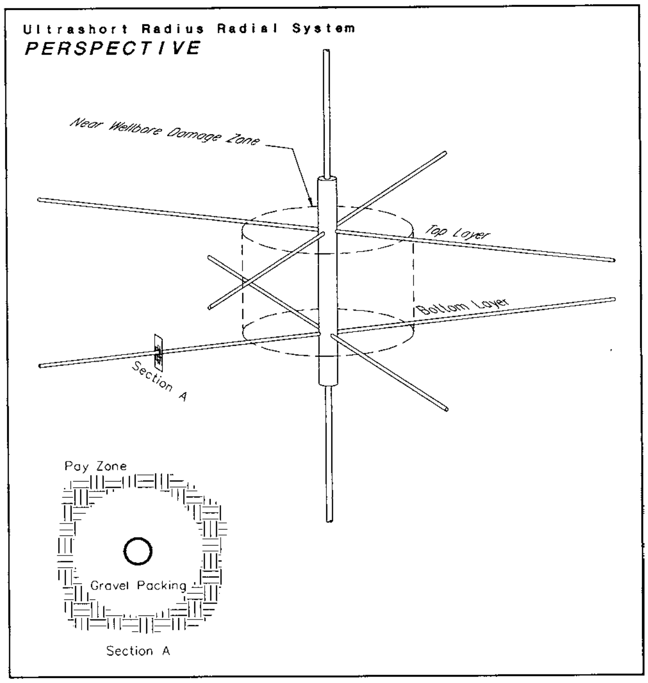
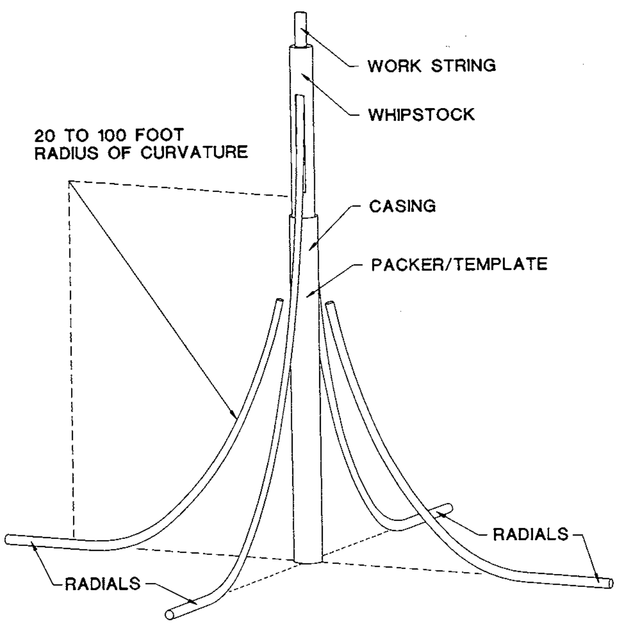
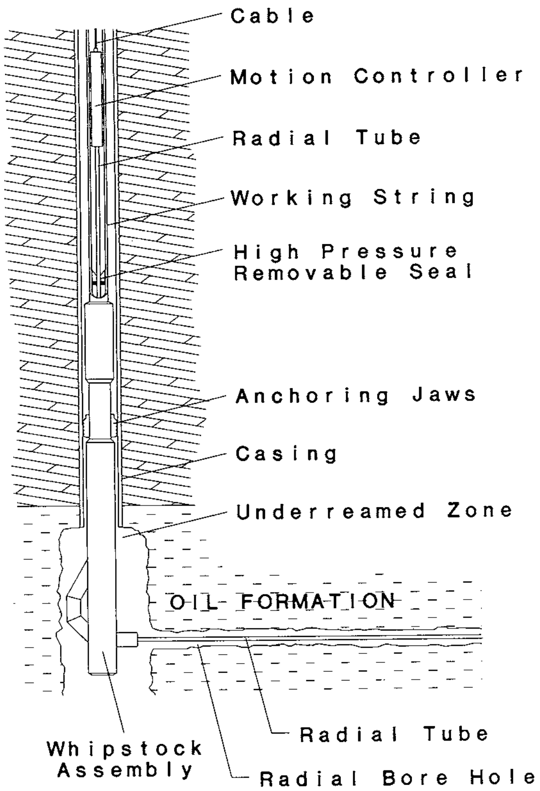


FIGURE 5



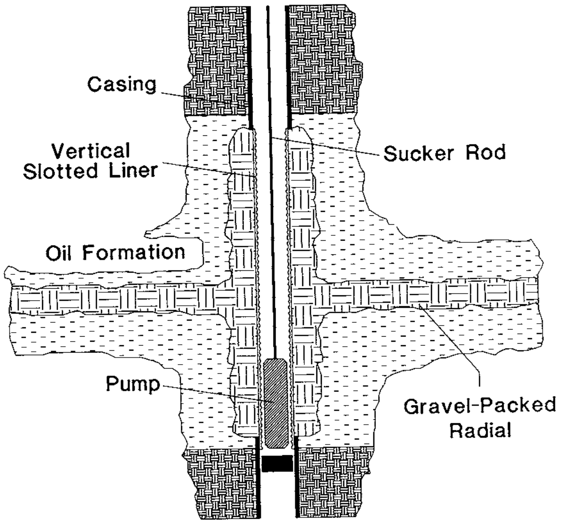
QUICK RADIAL SYSTEM

FIGURE 6



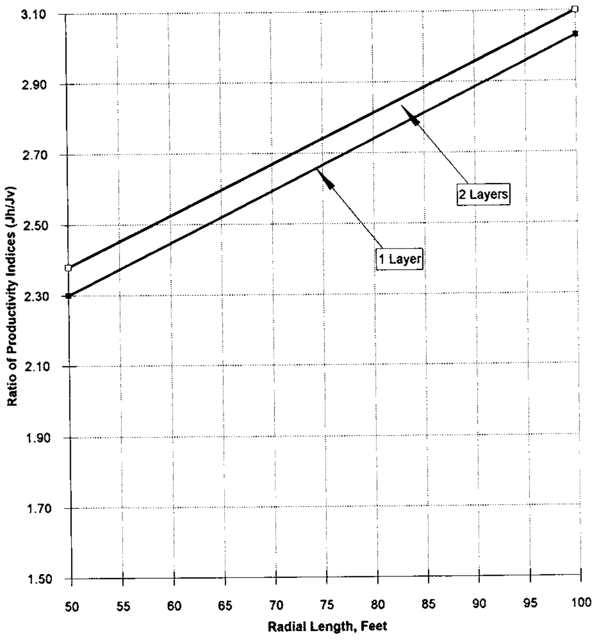
ULTRASHORT RADIUS RADIAL SYSTEM

FIGURE 7



COMPLETED ULTRASHORT RADIUS RADIAL SYSTEM WITH GRAVITY DRAINAGE

FIGURE 8



Ratio Of Productivity Index Of A Vertical Well With Two Horizontal Radials To That Of A Vertical Well In A 10-Ft Thick Reservoir With No Formation Damage

FIGURE 9

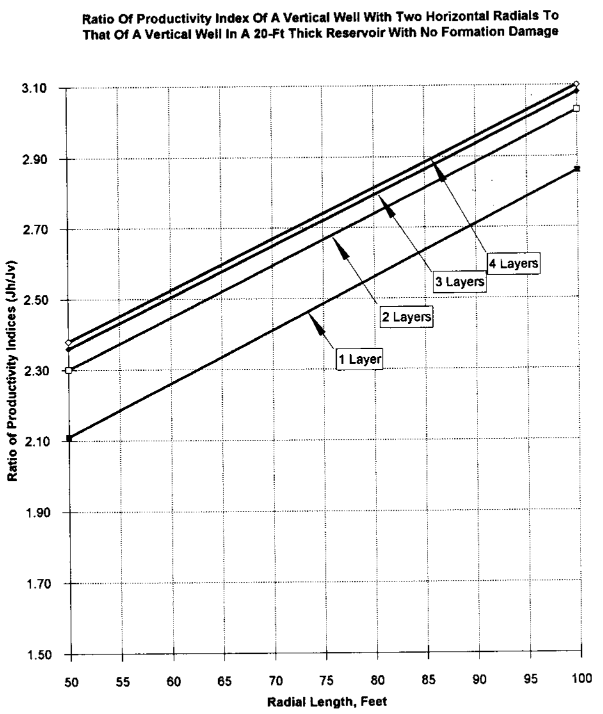


FIGURE 10

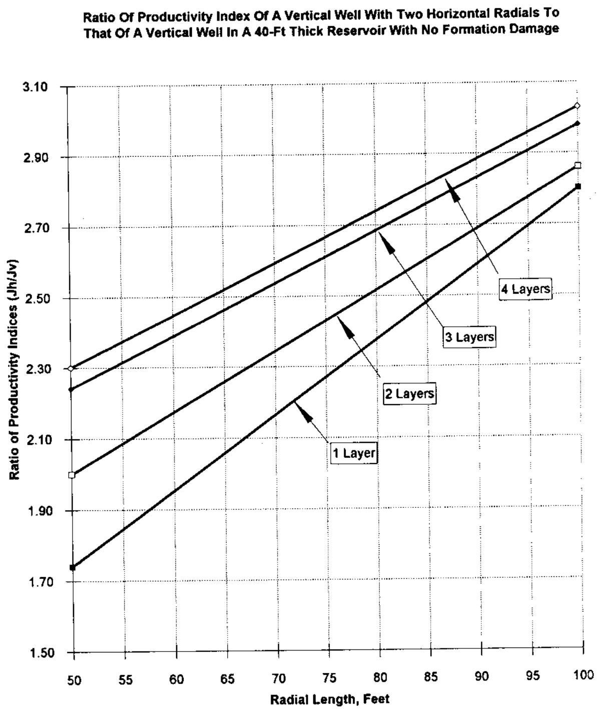
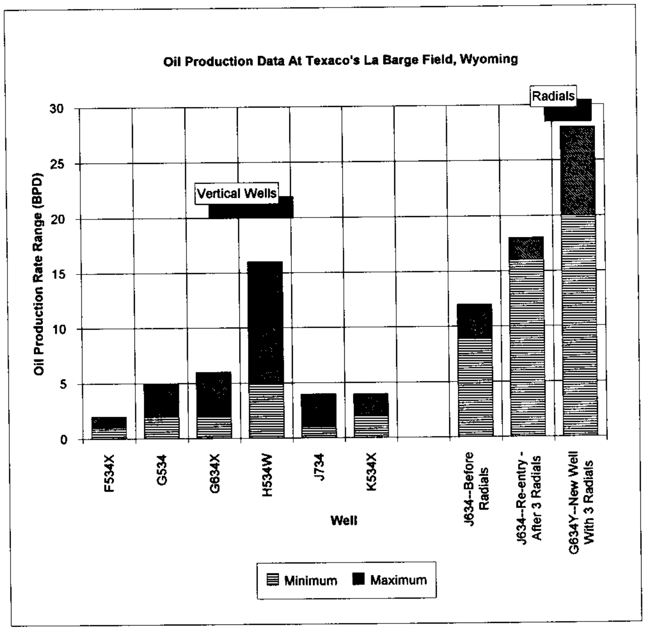


FIGURE 11



Wells	Water Production	Oil Production Declining Rate
F534X	Nearly Clean	
G534	Declining from 200 bwpd to 36 bwpd	
G634X	Declining from 160 bwpd to 25 bwpd	
H534W	Fluctuating from 1 bwpd to 2 bwpd	
J734	Fluctuating from 10 bwpd to 100 bwpd	
K534X	Fluctuating from 30 bwpd to 80 bwpd	
J634--Before Radials	Fluctuating from 2 bwpd to 5 bwpd	Declining 63% over 10 months
J634--Entry After 3 Radials	Nearly Clean	Declining 33% over 18 months
G634Y--New Well With 3 Radials	Increasing to 7 bwpd	Declining 49% over 18 months

FIGURE 12