# WATER CONING IN ASMARY RESERVOIR-FAUQI FIELD

Ass. Prof. Dr. Talib A. Saleh
College of Engineering
Petroleum Engineering Department
University of Baghdad

Shaker M. Khalaf
Ministry of Oil- South
Oil Company

**ABSTRACT**

Water coning in oil wells is one of the most serious problem because when the water reach to perforated zone, it will be produced with oil. Water with oil will form other problems in refinery, such as corrosion, and it will affect the purity of different petroleum products.

The present work deals with fauqi field Asmari reservoir which is an active water drive reservoir.

An empirical equation has been proposed to calculate the critical production rate. This equation is obtained by regression of the data which are collected from Missan oil field. The proposed equation gives better results than Schools and Myer equations when compared with the actual production rate.

الخلاصة :

يعتبر تقمع الماء في آبار النفط واحداً من المشاكل الخطيرة لأنه عندما يصل الماء الى منطقة التثقيب ينتج مع النفط . الماء مع النفط يشكل مشاكل أخرى في المصافي مثل التآكل ويؤثر على نقاوة المشتقات النفطية . هذا البحث يتعامل مع حقل الفكه مكمن الاسمري والذي يخضع الى دفع مائي نشيط . لقد تم الحصول على معادلة تجريبية لحساب معدل الانتاج الحرج . هذه المعادلة تم الحصول عليها من تحليل البيانات التي جمعت من حقل ميسان، مكمن الاسمري . المعادلة المقترحة تعطي نتائج افضل من طريقة شول وماير وغاردنر عندما تقارن بمعدل الانتاج الحرج الحقيقي.

## INTRODUCTION

Water and gas coning is considered as one of the serious problems that is faced in large number of oil fields.

Water coning depends on the properties of the porous medium, oil-water viscosity ratio, distance from the oil-water interface to the well, production rate, densities of the fluids and capillary effects. In oil recovery, water coning is highly unwanted. At high production rates, the water propagates upwards until the oil-water interface reaches the well. At this stage, the well begins to produce water and oil simultaneously, leading to lower oil production. At low production rates, the oil-water interface assumes a stable shape, and the well performance is not impaired. The estimate of the optimal production rate is thus crucial and the subject of most work on water coning.

In general, in water drive reservoirs, vertical wells, are usually completed in the upper section of the pay zone in order to reduce water coning. In addition ,vertical wells in reservoirs which have gas cap, are usually perforated as low as possible to be as far as possible from the oil-gas contact.

If there are two states of drive, the vertical well is normally perforated near the center of the oil zone or nearer to the oil- water contact. This is because the tendencies of coning are inversely proportional with the density difference and are directly proportional with viscosity.

The density difference between gas and oil is normally higher than the difference between water and oil. Therefore, gas tendency is less in water. However ,since viscosity of the gas is less than viscosity of water, then for the same pressure draw down, the flow rate of the gas is higher than the flow rate of water. The difference of the density and viscosity between water and gas tend to balance one another.

Therefore in order to decrease the gas and water coning perforations should be made near the center of the oil zone. From practical experience most of the wells are perforated nearer to the oil water contact rather than oil gas contact.

The naturally fractured reservoirs, especially those with vertical fractures could have severe coning in spite of high reservoir permeability. This is because water and gas move rapidly through high permeability (vertical) fractures. This is especially true in fractured reservoirs with low matrix permeability, and large matrix blockes where water imbibition in the matrix is very slow. In several fractured limestone and reef reservoirs coning problems are severe due to vertical fracturing.

Coning can be minimized by reducing pressure draw down , this can be attained by reducing oil producing rate , and in many instances , it is operationally impractical.

When flowing pressure gradient near the well bore causes gas or water flowing in the vertical direction across bedding planes, coning phenomena will occur and it will be steady when producing rate & flowing pressure gradient are constant.

If flowing pressure gradient is higher than that enough to overcome the gravity forces, then, water and gas coning will be unsteady.

Coning problem had been studied by many authors. Farely (1959), Morris (1964), Szilos (1975) presented empirical equations for calculating critical flow rate above which coning may occur. Quinet (1992), Guinard (1993) used electrical models to simulate coning problem, Phillip and Hasson (1994) proposed laboratory Model to simulate this problem.

## CRITICAL RATE

Since the early days, several experiments and mathematical analyses were conducted to solve coning problems. One of the basic analyses was if oil is produced at a sufficiently low rate or if pressure drawdown in a vertical well is reduced, coning of water and gas can be avoided, and only oil is produced. This low rate is called the critical rate. Thus, the critical rate is defined as the maximum rate at which oil is produced without production of gas or water.

### Vertical Well Critical Rate Correlations

Several vertical well critical rate correlations are available in the literatures, some of which are summarized in equations 1 to 9. It is important to note that these correlations are valid for a continuous oil pay zone with oil water contact or gas-oil contact or both. These correlations show that the critical rate depends upon effective oil permeability, oil viscosity, density difference between oil and water or oil and gas, well penetration ratio hp/h, and vertical permeability kv .

Craft and Hawkins(1959) Method

$$q_o = \frac{0.00708 k_o h (P_{ws} - P_{wf})}{\mu_o B_o \ln(r_e / r_w)} PR \tag{1}$$

$$PR = b'\left[1 + 7\sqrt{\frac{r_w}{2b'h}}\cos(b'90^o)\right] \tag{2}$$

Meyer and Gardner (1963) Method:

*Gas Coning:*

$$q_o = 0.001535 \frac{\rho_o - \rho_g}{\ln(r_e / r_w)} \left(\frac{k_o}{\mu_o B_o}\right) [h^2 - (h - h_p)^2] \tag{3}$$

*Water Coning:*

$$q_o = 0.001535 \frac{\rho_w - \rho_o}{\ln(r_e / r_w)} \frac{k_o}{\mu_o B_o} (h^2 - h_p^2) \tag{4}$$

*Simultaneous Gas and Water Coning :*

$$q_o = 0.001535 \frac{k_o}{\mu_o B_o} \frac{(h^2 - h_p^2)}{\ln(r_e / r_w)} \left[(\rho_w - \rho_o)\left(\frac{\rho_o - \rho_g}{\rho_w - \rho_g}\right)^2 + (\rho_o - \rho_g)\left(1 - \frac{\rho_o - \rho_g}{\rho_w - \rho_g}\right)^2\right] \tag{5}$$

Chapron(1986) Method:

$$q_o = \frac{3.486 \times 10^{-5}}{B_o} \frac{k_h h^2}{\mu_o} [\Delta\rho] q_c^* \qquad (6)$$

In the U.S. oil field units, Equation (6) can be rewritten as:

$$q_o = \frac{4.888 \times 10^{-4}}{B_o} \frac{k_h h^2}{\mu_o} [\Delta\rho] q_c^* \qquad (7)$$

The value of $qc^*$ is given in the following table as a function of α:

| α | $q_c^*$ |
|---|---|
| 4 | 1.2133 |
| 13 | 0.8962 |
| 40 | 0.7676 |

A correlation of tabulation is given in Equation (8):-

$q_C^* = 0.7311+(1.9434/\alpha)$ (8)

Where:

$\alpha = (r_e/h) \sqrt{k_v/k_h}$

Schols(1972) Method:

$$q_o = \frac{(\rho_w - \rho_o) k_o (h^2 - h_p^2)}{2049 \mu_o B_o} \times \left[ 0.432 + \frac{\pi}{\ln(r_e / r_w)} \right] [h / r_e]^{0.14} \qquad (9)$$

## PROPOSED CORRELATION

Data collected were for ten oil wells from missan oil field. The published correlations have been applied for these wells, but non of them have concide with actual critical production rate. The wells which have been exceeded these rates, water coning have occurred after a period of time shown in tables below. Therefore a trail was done to find an empirical equation satisfying these values. By the method of trial and error, the following equation was suggested which gave a very good degree of accuracy. In this equation two parameters were introduced these are; the capillary pressure and degree of heterogeneity of the reservoir which were not included in any other equation

$$q_0 \max = 0.00175\left(\frac{\rho w-\rho_0}{\ln(r_e/r_w)}\right)^{1.075}\left(\frac{K_o}{\mu_o Bo}\right)\left(h^{2.15}-D^{1.995}\right)(H.D)+87.8\ln P \qquad (10)$$

Where

$q_{0\ max}$ = critical production rate STB/D
$\rho_W$= water density gm/cc
$\rho_o$= oil density gm/cc
$r_e$= drainage radius ft
$r_w$ = well radius ft
$K_o$ = oil permeability md
$\mu_o$ = oil viscosity cp
$B_o$= oil formation volume factor bbl/STB
H= formation thickness in ft
D= distance ft
H.D= heterogeneity degree of reservoir -
PC = capillary pressure psia

The parameters involved in eq. (10) are measured in the laboratories of south oil company.

**Table (1)** qomax by proposed correlation

| | FQ-1 | | FQ-2 | | FQ-7 | | FQ-8T | | FQ-16 | |
|---|---|---|---|---|---|---|---|---|---|---|
| year | h\`(ft) | $q_{omax}$STB/D | h\`(ft) | $q_{omax}$STB/D | h\`(ft) | $q_{omax}$STB/D | h\`(ft) | $q_{omax}$STB/D | h\`(ft) | $q_{omax}$STB/D |
| 1999 | 141.5 | 412.94 | 89.09 | 717 | 127.8 | 730.49 | 134.37 | 1648.9 | 101.5 | 396.26 |
| 2000 | 141.4 | 412.76 | 88.99 | 715.8 | 127.7 | 729.83 | 134.27 | 1646.69 | 101.4 | 396 |
| 2001 | 141.1 | 412.23 | 88.69 | 712.17 | 127.4 | 727.86 | 133.97 | 1640 | 101.1 | 395.31 |
| 2002 | 140.9 | 411.91 | 88.51 | 710 | 127.2 | 725.82 | 133.79 | 1636.14 | 100.9 | 394.88 |
| 2003 | 140.9 | 411.82 | 88.46 | 709.4 | 127.2 | 723.76 | 133.74 | 1635 | 100.9 | 394.76 |

**Table (2)** the critical production rate by Schols, myer and Gardener

| FQ-10 | | | FQ-11 | | FQ-23 | | FQ-21A | | FQ-22A | |
|---|---|---|---|---|---|---|---|---|---|---|
| year | h`(ft) | $q_{omax}$STB/D | h`(ft) | $q_{omax}$STB/D | h`(ft) | $q_{omax}$STB/D | h`(ft) | $q_{omax}$STB/D | h`(ft) | $q_{omax}$STB/D |
| 1999 | 177 | 554.5 | 183.6 | 706.2 | 170.5 | 7048.3 | – | – | – | – |
| 2000 | 176.9 | 554.1 | 183.5 | 706 | 170.4 | 7048 | 139.3 | 940.6 | – | – |
| 2001 | 176.6 | 553.8 | 183.2 | 705.95 | 170.1 | 7047.5 | 139 | 940 | – | – |
| 2002 | 176.5 | 553.4 | 183 | 705.83 | 169.9 | 7046 | 138.8 | 939.6 | 114.6 | 1569.7 |
| 2003 | 176.4 | 552.9 | 182.9 | 704.9 | 169.9 | 7045.5 | 138.7 | 938.9 | 114.6 | 1569.1 |

Now this equation gives results very close to the actual rates which are given below in table (3).

Table (3) the actual production rate by South Oil Company

| year | FQ-1 | FQ-2 | FQ-7 | FQ-8 | FQ-16 |
|---|---|---|---|---|---|
| | $q_{omax}$STB/D | $q_{omax}$STB/D | $q_{omax}$STB/D | $q_{omax}$STB/D | $q_{omax}$STB/D |
| 1999 | 413 | 717.1 | 730.5 | 1649 | 396.3 |
| 2000 | 412.8 | 715.78 | 729.82 | 1646.7 | 396.1 |
| 2001 | 412.25 | 712.17 | 727.87 | 1640 | 395.31 |
| 2002 | 411.92 | 710 | 725.82 | 1636.15 | 394.88 |
| 2003 | 411.83 | 709.38 | 723.77 | 1635 | 394.78 |

| year | FQ-10 | FQ-11 | FQ-23 | FQ-21A | FQ-22A |
|---|---|---|---|---|---|
| | $q_{omax}$STB/D | $q_{omax}$STB/D | $q_{omax}$STB/D | $q_{omax}$STB/D | $q_{omax}$STB/D |
| 1999 | 554.6 | 706.19 | 7048.3 | – | – |
| 2000 | 554.12 | 706 | 7048.1 | 940.5 | – |
| 2001 | 553.8 | 705.96 | 7047.49 | 940 | – |
| 2002 | 553.39 | 705.83 | 7046 | 939.6 | 1569 |
| 2003 | 552.91 | 704.9 | 7045.51 | 938.95 | 1569.2 |

## CONCLUSIONS

- An Empirical equation was developed to calculate critical rate of (FAUQI field) and it gave accurate results compared with other methods.
- Trial and error method was used to find the empirical equation.

## NOMENCLATURE

| | |
|---|---|
| $q_{o\ max}$ = oil flow rate without water | STB/D |
| h' = elevation of water cone | ft |
| $\phi$ = porosity | |
| $q_L$ = liquid flow rate | STB/D |
| $q_w$ = water flow rate | STB/D |
| $p_c$= capillary pressure | Psi |
| $q_o$ = critical oil rate, | $m^3$/hr |
| $k_h$ = horizontal permeability | md |
| $k_v$ = vertical permeability | md |
| h= oil column thickness | m |
| $\mu_o$= viscosity, | cp |
| $\Delta\rho = \rho_w - \rho_o$ density difference | gm/cc |
| $\rho_w$ = water density | gm/cc |
| $\rho_o$ = oil density | gm/cc |
| $B_o$ = formation volume factor | Res $m^3$/St $m^3$ |
| $r_e$ = radius of drainage area | in |
| $r_w$ = radius of well | in |
| $K_o$= oil permeability | md |

## REFERENCES


- Chapron, " Theoretical Study of Coning Toward Horizontal and Vertical Wells in Anisotropic Formation , Sub critical and Critical Rates", Paper SPE 15377,Presented at the Annual Technical Conference and Exhibition, NewOrleans, Louisiana, Oct., 5-8, 1986.

- Craft,B,Cand Hawkins,M,F: "Applied petroleum Reservoir Engineering" ,Glewood Cliffs, New Jersey, Practice-Hall, 1959.

- FARELY F. J., "some aspects on the problems of oil wells",NEW-ZELAND , 1959.

- Guinard M$^{me}$,"Une circuit electrique", J.de (C.N.R.S) ,Oct.,28,1984.

- GUTTON C., "problem de formation de cone dleau dans le puits du petrol",rapport du universite du clermnt Ferrand,France 1978.

- Hel mut R.M, "something about the water cone formation in oil wells",S.P.E. NOV. 5-6 (1979).

- Jacque P. and Nadine, "Formation de cone dleau dane le puits du petrole",Universite descience et technologie,NANcy,France 1982.

- Jaune M. and A.Abass, "Cone dl eau arec la production du petrole",Seminare dl lmivers;du Marseille,france 15,NOV.,1986.

- MORRIS R. L., "Water coning in oil well is a great problem" ,A.I.M.E September 1964.

- Myer,H.L,and Gardener,A.O., "Mechanics of Two Immiscible Fluids in Porous Media", Journal of Applied Physics,vol.25,No.11 pp.1400, 1985.

- PHILLIP,O. and Hasson J., " Lab. Model to simulate the water coning in oil fields",J.P.T.,Nov. 1994.

- Quinet J., "Circuits electriques des amplificateurse", 1992.

- Schols,R,S., " An Empirical Formula for the Critical Oil Production Rates", Erdoel Erdgas,Z,vol.88,No.1,pp6-11,January 1972.

- Szilos,a.p., "production and transport of oil and gas development in petroleum science",elesevier scientific publishing company,Amesterdam,oxford,Newyork 1975.