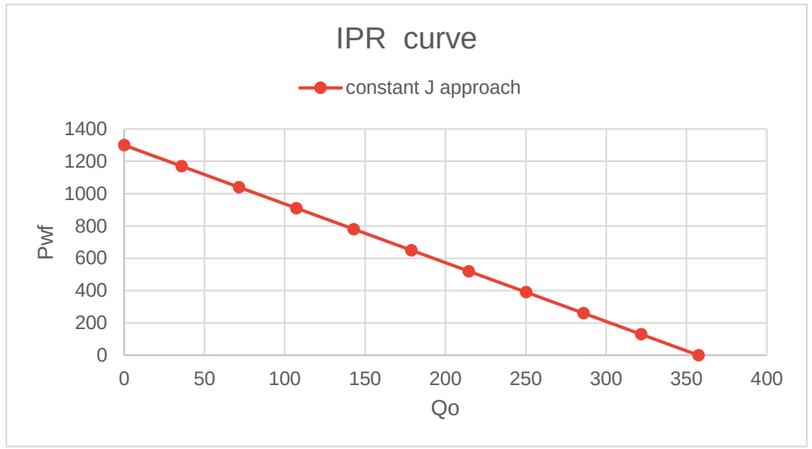
SIMPLE IPR CURVE FOR UNDERSATURATED RESERVOIR

Avg. Pr	1300	psi
(Pwf)stablized	900	psi
(Qo)stablized	110	STB/day

Productivity index	0.275	STB/day-psi
AOF	357.5	STB/day

data values for plotting IPR curve

Pwf	Qo
1300	0
1170	35.75
1040	71.5
910	107.25
780	143
650	178.75
520	214.5
390	250.25
260	286
130	321.75
0	357.5



Vogel's Method

Saturated oil reservoirs (pr ≤ pb)

Avg. Pr	2500	psi
$(Pwf)_{stablized}$	2000	psi
$(Qo)_{stablized}$	350	STB/day

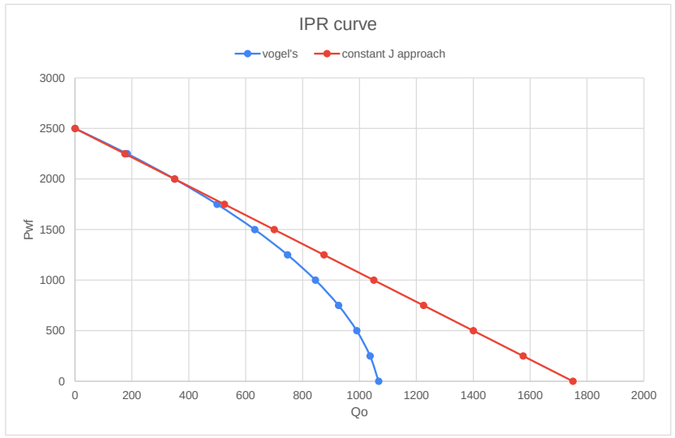
data for plotting IPR curve

	vogel's	*constant J approach*
Pwf	**Qo**	**Qo**
2500	0	0
2250	183.5365854	175
2000	350	350
1750	499.3902439	525
1500	631.7073171	700
1250	746.9512195	875
1000	845.1219512	1050
750	926.2195122	1225
500	990.2439024	1400
250	1037.195122	1575
0	1067.073171	1750

$$(Q_o)_{max} = Q_o \Big/ \left[1 - 0.2\left(\frac{p_{wf}}{p_r}\right) - 0.8\left(\frac{p_{wf}}{p_r}\right)^2\right]$$

J	0.7	STB/day-psi
$(Qo)max$	1067.073171	STB/day

$$Q_o = (Q_o)_{max}\left[1 - 0.2\left(\frac{p_{wf}}{p_r}\right) - 0.8\left(\frac{p_{wf}}{p_r}\right)^2\right]$$



Undersaturated oil reservoirs (pr > pb)

Avg. Pr	3000	psi
$(Pwf)_{stablized}$	2500	psi
$(Qo)_{stablized}$	250	STB/day
Pb	2130	psi

CASE 1:
The recorded stabilized bottom-hole flowing pressure is greater than or equal to the bubble-point pressure, i.e. pwf ≥ pb

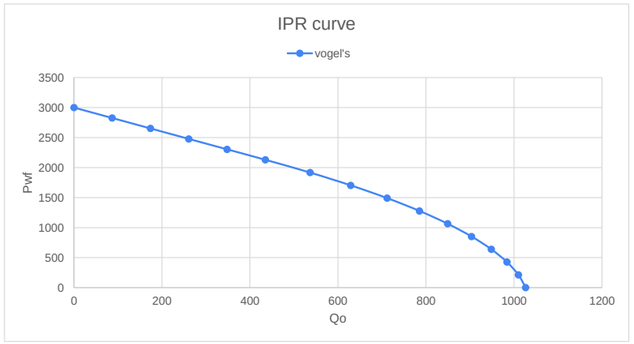
J	0.5	STB/day-psi
Qob	435	STB/day
(Qmax)vogel	591.6666667	STB/day

$$J = \frac{Q_o}{P_r - P_{wf}} \qquad Q_{ob} = J\,(\bar{p}_r - P_b)$$

Pwf	Qo
3000	0
2826	87
2652	174
2478	261
2304	348
2130	435
1917	536.7666667
1704	629.0666667
1491	711.9
1278	785.2666667
1065	849.1666667
852	903.6
639	948.5666667
426	984.0666667
213	1010.1
0	1026.666667

$$Q_o = J\,(\bar{p}_r - p_{wf}).$$

$$Q_o = Q_{ob} + \frac{Jp_b}{1.8}\left[1 - 0.2\left(\frac{p_{wf}}{p_b}\right) - 0.8\left(\frac{p_{wf}}{p_b}\right)^2\right]$$



Undersaturated oil reservoirs (pr > pb)

Avg. Pr	3000	psi
$(Pwf)_{stablized}$	1700	psi
$(Qo)_{stablized}$	630.7	STB/day
Pb	2130	psi

CASE 2:
The recorded stabilized bottom-hole flowing pressure is less than the bubble-point pressure pwf < pb

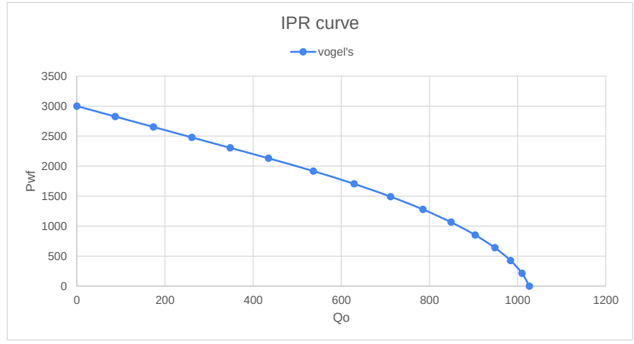
J	0.499992515	STB/day-psi
Qob	434.993488	STB/day
(Qmax)vogel	591.6578093	STB/day

$$J = \frac{Q_o}{\left(\bar{p}_r - p_b\right) + \frac{p_b}{1.8}\left[1 - 0.2\left(\frac{p_{wf}}{p_b}\right) - 0.8\left(\frac{p_{wf}}{p_b}\right)^2\right]} \qquad Q_{ob} = J\,(\bar{p}_r - P_b)$$

Pwf	Qo
3000	0
2826	86.99869759
2652	173.9973952
2478	260.9960928
2304	347.9947904
2130	434.993488
1917	536.7586312
1704	629.0572494
1491	711.8893427
1278	785.2549111
1065	849.1539545
852	903.5864729
639	948.5524664
426	984.051935
213	1010.084879
0	1026.651297

$$Q_o = J\,(\bar{p}_r - p_{wf}).$$

$$Q_o = Q_{ob} + \frac{Jp_b}{1.8}\left[1 - 0.2\left(\frac{p_{wf}}{p_b}\right) - 0.8\left(\frac{p_{wf}}{p_b}\right)^2\right]$$



IPR CURVE USING FETKOVITCH MODEL

$$Q_o = \frac{0.00708\,kh}{\left[\ln\frac{r_e}{r_w} - 0.75 + s\right]}\int_{pwf}^{\bar{p}_r} f(p)\,dp \qquad f(p) = \frac{k_{ro}}{\mu_o \beta_o}$$

Saturated oil reservoirs (pr ≤ pb)

Avg. Pr	3600	psi

Qo, STB/day	pwf, psi	(Pr^2 - Pwf^2)
263	3170	2911100
383	2890	4607900
497	2440	7006400
640	2150	8337500

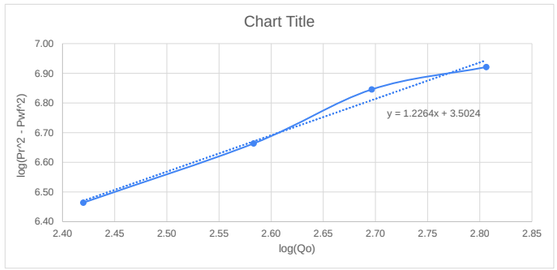
$$f(p) = \left(\frac{1}{\mu_o B_o}\right)_{pb}\left(\frac{p}{pb}\right)$$

$$Q_o = \left|\frac{0.00708\,kh}{\ln\left(\frac{r_e}{r_w}\right) - 0.75 + s}\int_{p_{wf}}^{\bar{p}_r}\frac{1}{(\mu_o B_o)_{pb}}\left(\frac{p}{p_b}\right)dp\right| \quad Q_o = J\left(\frac{1}{2p_b}\right)\left(\bar{p}_r^{\,2} - p_{wf}^2\right) \quad Q_o = C\left(\bar{p}_r^{\,2} - p_{wf}^2\right)^n$$

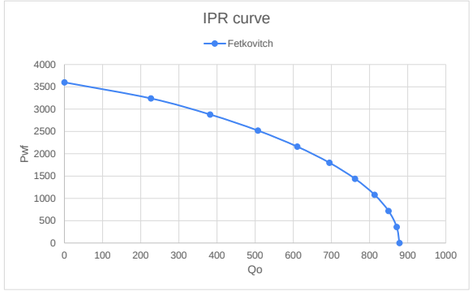
log(Qo)	log(Pr^2 - Pwf^2)
2.42	6.46
2.58	6.66
2.70	6.85
2.81	6.92

$$\log\left(\bar{p}_r^{\,2} - p_{wf}^2\right) = \frac{1}{n}\log Q_o - \frac{1}{n}\log C$$

slope	1.2264304
intercept	3.5023980
n	0.8153744
C	0.0013939



Pwf	Qo
3600	0
3240	226.7695
2880	381.8483
2520	507.2600
2160	610.4282
1800	694.7021
1440	761.9557
1080	813.3432
720	849.6007
360	871.1872
0	878.3557



Undersaturated oil reservoirs (pr > pb)

Avg. Pr	3000	psi
(Pwf)stablized	2200	psi
(Qo)stablized	280	STB/day
Pb	1500	psi

h	20	in
rw	0.3	in
re	660	in
uo at 2600psi	2.4	cp
Bo at 2600psi	1.4	bbl/STB
S	-0.5	---
K	65	md

$$f(p) = \left(\frac{1}{\mu_o B_o}\right)_p$$

value of uo and Bo is measured at (Pr+Pwf)/2

CASE 1:

The recorded stabilized bottom-hole flowing pressure is greater than or equal to the bubble-point pressure, i.e. pwf ≥ pb

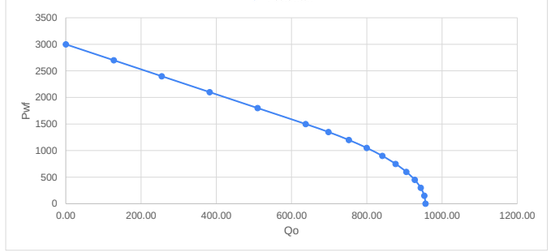
$$Q_o = \frac{0.00708\,kh}{\ln\left(\frac{r_e}{r_w}\right) - 0.75 + s}\int_{pwf}^{\bar{p}_r}\left(\frac{1}{\mu_o B_o}\right)dp \qquad Q_o = \frac{0.00708\,kh}{\mu_o B_o\left[\ln\left(\frac{r_e}{r_w}\right) - 0.75 + S\right]}\left(\bar{p}_r - p_{wf}\right)$$

J	0.424944982	STB/day-psi

Pwf	Qo
3000	0.00
2700	127.48
2400	254.97
2100	382.45
1800	509.93
1500	637.42
1350	697.97
1200	752.15
1050	799.96
900	841.39
750	876.45
600	905.13
450	927.44
300	943.38
150	952.94
0	956.13

$$Q_o = J\left(\bar{p}_r - p_{wf}\right)$$

$$Q_o = J\left[\frac{1}{2p_b}\left(p_b^2 - p_{wf}^2\right) + \left(\bar{p}_r - p_b\right)\right]$$



Undersaturated oil reservoirs (pr > pb)

Avg. Pr	4000	psi
(Pwf)stablized	3000	psi
(Qo)stablized	700	STB/day
Pb	3200	psi

$$f(p) = \left(\frac{1}{\mu_o B_o}\right)_{pb}\left(\frac{p}{pb}\right) \qquad f(p) = \left(\frac{1}{\mu_o B_o}\right)_p$$

CASE 2:

The recorded stabilized bottom-hole flowing pressure is less than the bubble-point pressure pwf < pb

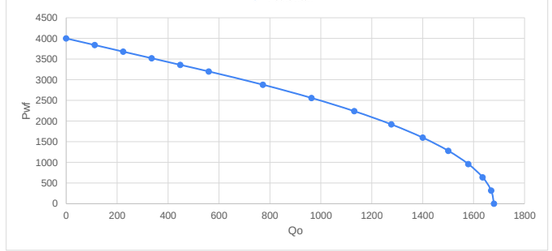
$$Q_o = \frac{0.00708\,kh}{\ln\left(\frac{r_e}{r_w}\right) - 0.75 + s}\left[\int_{p_{wf}}^{pb} f(p)\,dp + pb\int_{pb}^{\bar{p}_r} f(p)\,dp\right]$$

J	0.7	STB/day-psi

Pwf	Qo
4000	0
3840	112
3680	224
3520	336
3360	448
3200	560
2880	772.8
2560	963.2
2240	1131.2
1920	1276.8
1600	1400
1280	1500.8
960	1579.2
640	1635.2
320	1668.8
0	1680

$$Q_o = J\left(\bar{p}_r - p_{wf}\right)$$

$$Q_o = J\left[\frac{1}{2p_b}\left(p_b^2 - p_{wf}^2\right) + \left(\bar{p}_r - p_b\right)\right]$$



Field case 3: Well B, Keokuk Pool, Seminole County, Oklahoma, August 1935

Saturated reservoir

Pr	1714	psi
Pb	3420	psi
C1	0.41	

Multi-rate test data

Pwf (psi)	Oil Rate (bbl/day)	
1714	0	
1583	280	
1443	508	***test point (for two point correlation's)***
1272	780	
1196	1125	***test point (for single point correlation's)***
982	1335	

IPR curve by using New correlation

C1	0.41	
(Qo)max	2636.899892	STB/day

$$\frac{q_o}{q_{o\max}} = 1 - C_1\left[\frac{P_{wf}}{P_r}\right] - \left(1 - C_1\right)\left[\frac{P_{wf}}{P_r}\right]^2$$

Pwf	Qo
1714	0
1583	311.3553721
1443	624.0096558
1272	977.7314268
1196	1125
982	1506.812135
800	1793.363642
600	2067.796199
400	2299.863093
200	2489.564324
0	2636.899892

IPR curve by using Vogel's method

(Qo)max	2388.927833	STB/day

Pwf	Qo
1714	0
1583	317.4879492
1443	632.106709
1272	981.7948926
1196	1125
982	1487.863165
800	1749.580982
600	1987.482024
400	2173.340179
200	2307.155449
0	2388.927833

IPR curve by using Fetkovitch's method

Multi-rate test data

	Pwf (psi)	Oil Rate (bbl/day)	(Pr^2-Pwf^2)	log(Qo)	log(Pr^2-Pwf^2)
	1714	0	0	*null*	*null*
	1583	280	431907	2.447158031	5.635390243
test point	1443	508	855547	2.705863712	5.932243873
	1272	780	1319812	2.892094603	6.120512073
test point	1196	1125	1507380	3.051152522	6.178222749
	982	1335	1973472	3.125481266	6.295230969

using test points to calculate C and n

Pwf	log(Qo)	log(Pr^2-Pwf^2)	
1443	2.705863712	5.932243873	***test point***
1196	3.051152522	6.178222749	***test point***

intercept	4.004624747
slope	0.712385889

C	2.39097E-06
n	1.403733588

Pwf	Qo
1714	0
1583	194.607826
1443	508
1272	933.5597266
1196	1125
982	1642.104878
800	2033.107343
600	2389.233856
400	2653.458781
200	2815.75826
0	2870.469609

		New correlation	***Vogel's***	***Fetkovitch's***
Pwf (psi)	Oil Rate (bbl/day)	Qo	Qo	Qo
1714	0	0	0	0
1583	280	311.3553721	317.4879492	194.607826
1443	508	624.0096558	632.106709	508
1272	780	977.7314268	981.7948926	933.5597266
1196	1125	1125	1125	1125
982	1335	1506.812135	1487.863165	1642.104878

Percentage Error

New correlation	***Vogel's***	***Fetkovitch's***
11.19834719	13.38855328	30.49720499
22.83654641	24.43045453	2.57362E-13
25.35018292	25.87114008	19.68714444
0	0	2.62743E-13
12.86982287	11.45042437	23.00411072
14.45097988	15.02811445	14.63769203

Average absolute errors