PRODUCTION ENHANCEMENT BY REDUCING FORMATION DAMAGE OF AMAL FIELD

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Abstract

Experience in the oil industry has indicated that many oil wells have suffered flow restriction because of scale deposition within the oil producing formation through matrix and the down hole equipment.

Scale in oil field, just like the scale found in home plumbing or tea kettles, can be deposited all along water paths from injectors through the reservoir to surface equipment. Most scale found in oil fields forms either by direct precipitation from the water that occurs naturally in reservoir rocks, or because of produced water becomes over saturated with scale components when two incompatible waters meet down hole.

To tackle the effect of inorganic scale (Calcium Carbonate) on well productivity, three wells from Amal field namely B96, B20 and B72 have been included in this study. Most of the wells in Amal field, area B, were subjected to the same kind of in organic scale, and to the test of scale solubility, and all samples were successfully dissolved in HCL.

Prosper software as well performance tool was used to generate models of inflow and out flow curves before and after stimulation job was done to those wells. The results showed a significant increase in production.

Formation Damage

Introduction

Formation damage indicators include permeability impairment, skin, damage and decrease of well performance. Flow of suspensions in rocks with particle capture and consequent permeability impairment is an essential phenomenon in many oil industry processes. Particle capture by rock and permeability decline takes place during drilling fluid invasion into reservoir resulting in formation damage. It also occurs during fines migration, mostly in reservoirs with low consolidated sands and heavy oil.

Diagnosis of formation damage allows choosing the right damage-removal technology during seawater injection to enhance the recovery factor of hydrocarbon reservoirs. The particle-storage capacity function is a rheological characteristic that closes system of governing equations. The particle erosion can be defined by the introduction of a new particle storage capacity function that equals the maximum retained concentration versus dimensionless flow velocity.

Deep bed filtration of fines with capture and permeability damage takes place near production wells during drilling operation. The particles, in drilling, fluid are captured by size exclusion (straining) or by different attachment mechanisms (electric forces, gravity segregation and diffusion). The analysis for deep bed filtration shows that injectivity stabilizes when time tends to infinity.

Overview of Amal Field

Amal Field was discovered in 1959 in the Sirte basin and it is the Harouge’s largest and most important oil field. Harouge’s concession consists of eight reservoirs ranging in depth from 2,300 to 12,000 ft. It is located along the eastern flank of Sirte Basin in Concession 12. This field covers an area of 151,000 acres. The area is subdivided in three main reservoirs namely B, N & E on basis of oil PVT properties and pressure/production performance. These three reservoirs share a common aquifer and have an original field average oil/water contact at 10250' SS.

Amal Field includes 191 wells six of which, drilled as appraisal wells, were abandoned. The wells in "B" and "N" reservoirs were initially drilled at 2.0 Km spacing and later, on infill wells, were drilled at 1.4 Km. In some portions of "E" reservoir the wells are still in excess of 4.0 KM spacing.

Amal field serves other oil operators in the area by storing and forwarding crude oil to the Ras Lanuf port. The Amal field area produces approximately 400,000 barrels per day of crude oil which accounts for about one third of Libya’s national production.

Area (B) of Amal Field

Amal "B" reservoir is located in the most southern area of the Amal field. It was constituted by two main producing formations: Maragh and Amal. Maragh formation is divided into two basic units A and B while Amal formation is divided into five basic units in an ascending order from Amal unit-I for the oldest one to Amal unit-V for the more recent one.

Each of Amal formation units were subdivided in up to five sub-units which are labeled by A, B,…, E from bottom to top to identify the location of the best development of reservoir quality sandstone occurs. Amal is an unconformable reservoir that overlies in several places by carbonate members of Rakb basal formation.

In significant portions of the "B" reservoir, the Maragh formation, with its friable conglomeratic sandstone, overlays the Amal formation. Maragh in B Area consists of sandstone members of hard rock type exhibiting a wide variation in reservoir rock characteristics and production potential. Some Amal units consist of a tight matrix rock with varying fractured system. Some units of Amal formation are tight and may not contribute to production.

The Maragh and Amal producing horizons are commingled to the well production stream in the wells that occur. Consequently, production by individual horizon cannot be identified directly except in scattered single unit completion or eventual production log profiles that run during the production history. The reservoir is highly under-saturated; its average oil gravity is 36° API and its saturation pressure 1840 psig.

One hundred and fifteen wells have been drilled in B Area, eight of which have been abandoned. The Oil recovery mechanism of Amal "B" reservoir is by an active bottom water drive. The reservoir pressure varies across the reservoir from 2013 psig to about 4500 psig. The current reservoir pressure in this reservoir has increased above the bubble point pressure of 1840 psig due to the shut-in period.

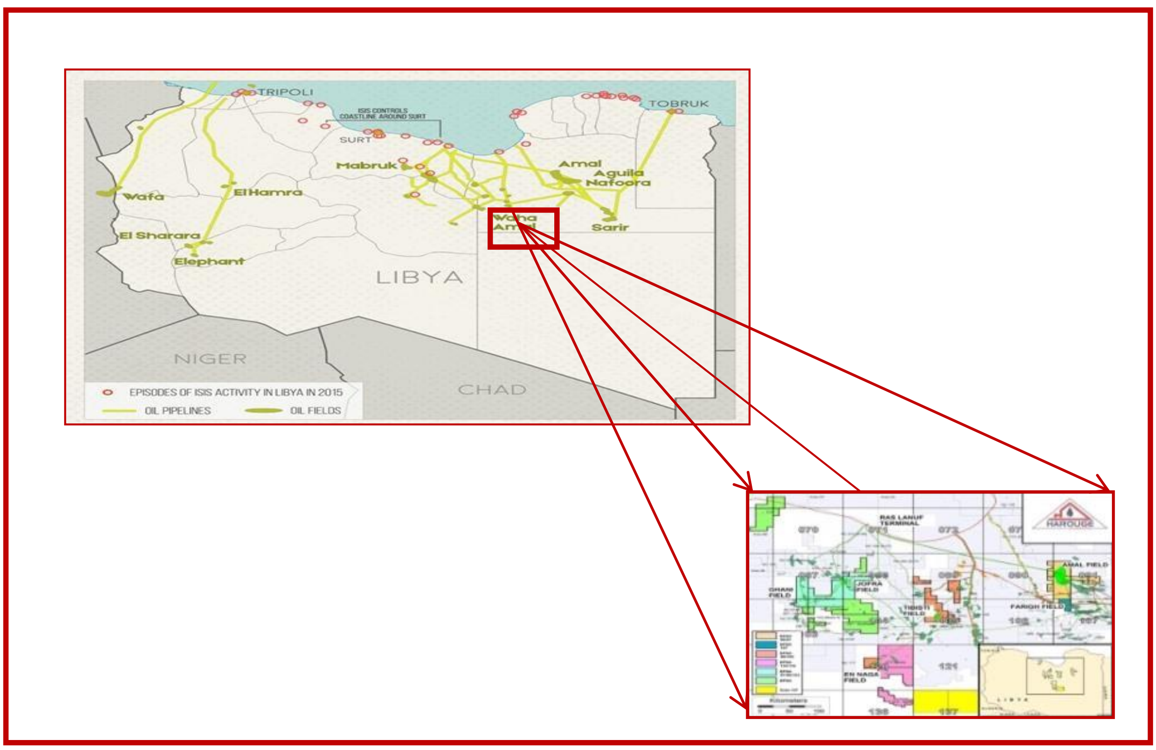

Figure (1): Location of the Field.

Building the Base Models for the Wells:

Choosing PVT Correlations

The purpose of this section is to build fluid properties model that can calculate properties at any change of temperature and pressure. First measured data of PVT and fluid properties have to be input then these data need to be matched to one of the correlations used in the software in order to predict the properties at any condition required. The correlations used are:

- Standing correlation
- Glaso correlation
- Laster correlation
- Vazquez-Beggs correlation
- Petroskyetal correlation

In the software two correlations must be chosen, one for the (Pb, βo, Rs) properties which have the above correlations range, and the other for the viscosity (μ) and have the following correlations to choose between them:

- Bealetal.
- Beggsetal.
- Petroskyetal.

Table (1): Farrud PVT & Fluid Analysis.

Bubble-point pressure	Psig	1855
Temperature	Fo	225
API gravity	API	36
Gas gravity	air=1	0.95
Solution gas oil ratio	scf/stb	507
WaterSalinity	ppm	190000
H2Smole percent	%	0
CO2molepercent	%	0
N2 mole percent	%	0
FVF	rb/stb	1.383
Rs	cf/scf	507
μo	Cp	0.840

Equipment Data Input

For the software to calculate the pressure drop in the well the following wellbore data must be provided:

1. deviation survey which shows whether the well is vertical or directional (by entering the measured depth versus the vertical depth).
2. downhole equipment data which includes the sizes, depths and types of the equipment used down in the well starts from the tubing down to the perforations
3. temperature survey which indicates the temperature gradient along the well flow stream.

Choosing the IPR Model

In this section, the inflow performance curve will be built by choosing one of the models in the PROSPER software and here are some of them:

1. PIEntry
2. Vogel
3. Composite
4. Darcy
5. Fetkovichor Multirate Fetkovich
6. Jones or Multi rate Jones
7. Transient(etc...).

Selection of Vertical Lift Performance (VLP) Correlation

In this section, one of the following correlations that matches the measured data of well testing and flowing gradient survey for all wells will be chosen.

1. Hagedorn Brown
2. DunsandRos Modified
3. Fancher Brown
4. Mukerijee Brill
5. Beggsand Brill
6. Petroleum Experts
7. Orkiszewski
8. PetroleumExperts2
9. DunsandRos Original
10. PetroleumExparts3
11. GRE (Modified byPE)
12. PetroleumExperts4

VLP/IPR Matching

Then IPR will be matched with VLP to complete the full model of a single well performance evaluation. In this section, the intersection of the IPR and VLP will be matched to the test points of each well.

Optimization Analysis of the Wells

The meaning of optimization is bringing the production into the maximum with minimum possible cost expenses. Accordingly, the researchers decided to use the following optimization procedure:

Through the current time and wells conditions the researchers changed the most flexible parameters of the well system namely well head pressure and tubing size, then decided whether these changes would last for long time or just start designing one of the artificial lift methods.

The researchers defined the parameters that the well will die at, then based on these parameters the artificial lift was designed.

Analysis of Well (B-96, Amal Field)

Well Information

- B-96 was completed in March 1995. The open hole Amal tested low fluid while 20’ perforated Maragh flowed to surface. Initially, the well produced 1492 BOPD with no water. Recently it has accumulated a total production of 2.56 million Bbl of oil and 0.71 million Bbl of water.
- The well is known for the formation scale deposits across perfs and above, reducing productivity from the well. In 4 of the 5 workover, production decreased from 1000 BOPD to 63 BOPD. The well worked over in Mar 2008 for cleaning out fill and stimulation. Immediately after the workover the well started production H2S and a casing leak was expected but after the workover, no leak was detected in the casing, the well was stimulated, and ESP was installed to produce 720 BOPD & 1800 PWPD.
- Another workover was in Jun 2010 to stimulate the well and change out ESP failure; 700 BOPD and 350 BWPD were produced until 6/12/2012 when a down hole failure was reported.
- The last work over was carried out in December 2017, cleaned out fill to PBTD @ 10020 ft. KB, tested casing for 500 psi OK and RIH GN1600, 180 stages. The well produced until 20 January 2018 (about 51 days) when the ESP failed.
- The well started up production with initial production parameters:

Table (2): Initial Production Parameter for Well (B-96).

Pr (psi)	QL(BFPD)	Pwf(psi)	WC (%)
2000	649	1600	0

- In the period 17 Dec 1997, several scale removal jobs were carried out to increase the well productivity as the table below:

Table (3): Scale Removal Jobs for Well (B-96).

Date	QL(BFPD)	WC (%)	Remarks
1/12/1997	117	0.4	Before scale removal
1/1/1998	284	0.4	After scale removal

Input Data

Table (4): Well (B-96) Information.

Well Name	B-96
Well Orientation	Vertical well
Well Completion	Open Hole
Formation Type	Maragh
Reservoir pressure(psi)	2000
Type acid	15 %HCL

Calculation of Change in Oil Flow Rate

$$\Delta q_o = \frac{q_{o-after} - q_{o-befur}}{q_{o-befur}} = \frac{284-117}{117} * 100 = 142.7\%$$

IPR curve before and after scale treatment with HCL

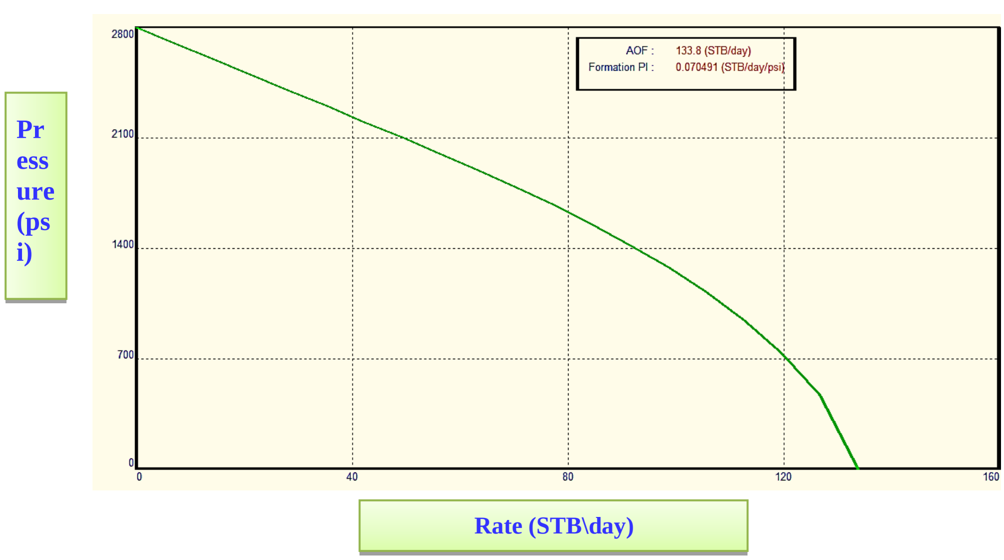

Figure (2): IPR Plot before Scale Removal for Well (B-96).

From the IPR curve, it can be observed that Absolute Open Flow potential (AOF) is about 133.8 (STB/day) and productivity index (J) = 0.070491 (STB/day/psi) .

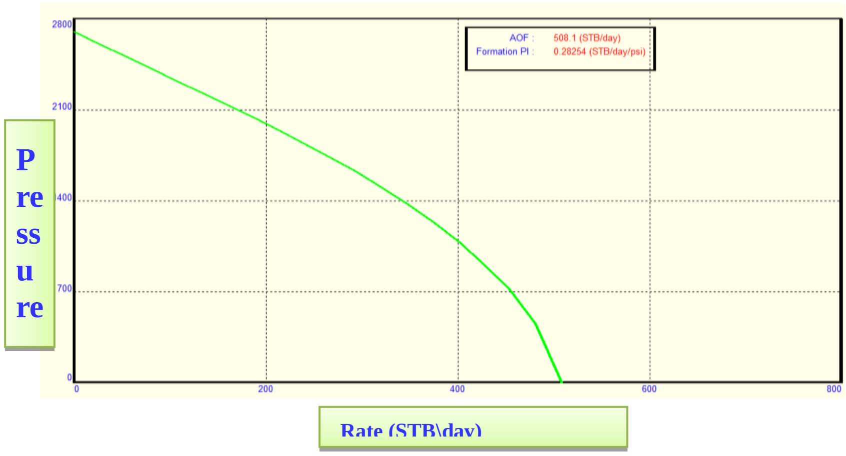

Figure (3): IPR Plot after Scale Removal for Well (B-96).

From the IPR curve, it can be observed that Absolute Open Flow potential (AOF) is about 508.1 (STB/day) and productivity index (J) = 0.28254 (STB/day/psi) .

Analysis of Well (B-72, Amal Field)

Well information

- This well was drilled in 1969.
- While drilling12 ¼" hole in the Mesdar formation, 400 bbls of mud were lost from 5200' to 5900' KB. At 7985' KB the drill pipe parted and was recovered. Lost 500 bbls of mud at 9256'KB in the Kalash formation. At 9532'KB drill collars parted and were recovered. The borehole was then reduced to 9 7/8" and at 9734' KB the drill collars twisted off. The fish was recovered and drilling continued to a depth of 10356'KB.
- 7" production casing was run with a Triplex shoe and cemented from 10355'KB. The cement was placed in plug flow. Cement inside the 7" casing was drilled down from 10264'KB to 10353' KB .
- The well started up production with initial production parameters:

Table (5): Initial Production Parameter for Well (B-72).

Pr (psi)	QL(BFPD)	Pwf (psi)	WC (%)
4300	275	1332	0.2

- In the period 28 Jun1984, several scale removal jobs were carried out to increase the well productivity as the table below shows.

Table (6): Scale Removal Jobs for Well (B-72).

Date	QL(BFPD)	WC (%)	Remarks
1/6/1984	694	46.5	Before scale removal
1/7/1984	769	50.4	After scale removal

Input Data

Table (7): Well (B-72) Information.

WellName	B-72
Well Orientation	Vertical well
Well Completion	Open Hole
Formation Type	Maragh
Reservoir pressure psi)	4300
Type acid	15 %HCL

Calculation of Change in Oil Flow Rate

$$\Delta q_o = \frac{q_{0-after} - q_{o-befur}}{q_{o-befur}} = \frac{769-674}{674} * 100 = 10.8\%$$

IPR Curve before and after Scale Treatment With HCL

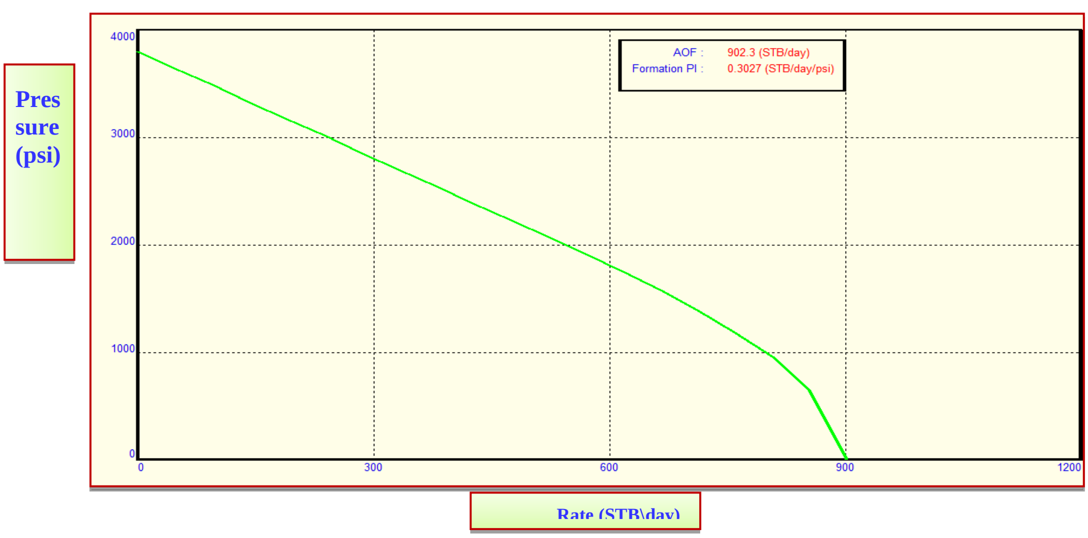

Figure (4): IPR plot before Scale Removal for Well (B-72).

From the IPR curve, it can be observed that Absolute Open Flow potential (AOF) is around 902.3 STB/day and productivity index (J) = 0.31916 STB/day/psi .

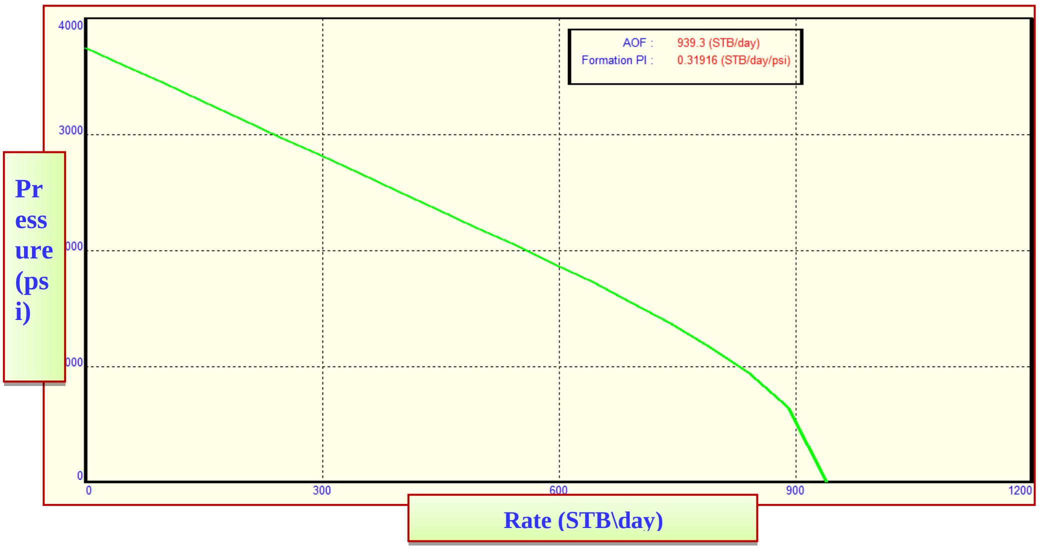

Figure (5): IPR Plot after Scale Removal for Well (B-72).

From the IPR curve, it can be observed that Absolute Open Flow potential (AOF) is around 939.3 STB/day and productivity index (J) = 0.31916 STB/day/psi .

Analysis of Well (B-20, Amal Field)

Well Information

- The well was drilled in Jan 1965 and since then had 4 workovers with the last one being in Jun 1997.
- The well was put on productionon1/8/1966
- The well started up production with initial production parameters:

Table (8): Initial Production Parameter for Well (B-20).

Pr (psi)	QL(BFPD)	Pwf(psi)	WC (%)
4200	221	2045	0

On 29 Oct 1969, several scale removal jobs were carried out to increase well productivity as the table below shows.

Table (9): Scale Removal Jobs for Well (B-20).

Date	QL(BFPD	WC (%)	Remarks
1/10/1969	251	0.7	Before scale removal
1/11/1969	262	0.7	After scale removal

Input Data

Table (10): WellB-72 Information.

Well Name	B-72
Well Orientation	Vertical well
Well Completion	Open Hole
Formation Type	Maragh
Reservoir pressure (psi)	4200
Type acid	15 %HCL

Calculation of Change in Oil Flow Rate

$$\Delta q_o = \frac{q_{o-after} - q_{o-befur}}{q_{o-befur}} = \frac{262 - 251}{251} * 100 = 4.38\%$$

IPR Curve Before and after Scale Treatment with HCL

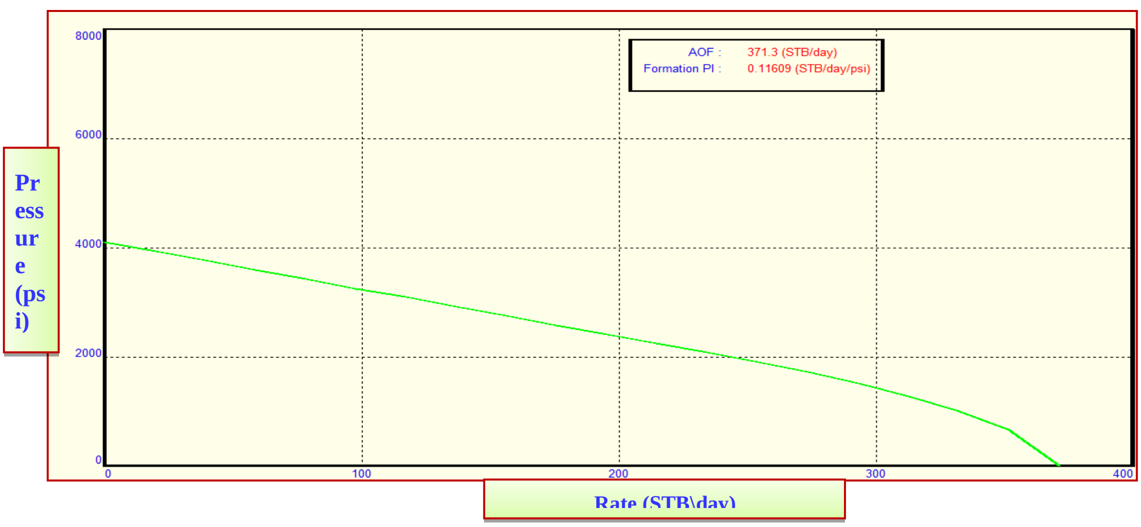

Figure (6): IPR Plot before Scale Removal for Well (B-20).

From the IPR curve, it can be observed that Absolute Open Flow potential (AOF) is around 371.3 STB/day and productivity index (J) = 0.11609 STB/day/psi.

From the IPR curve, it is observed that Absolute Open Flow potential (AOF) is around 373.5 STB/day and productivity index (J) = 0.12056 STB/day/psi.

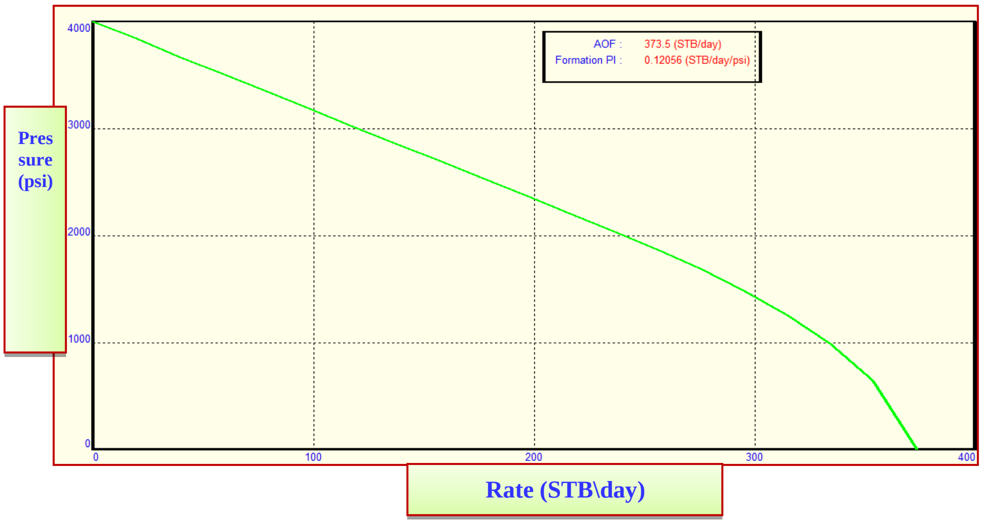

Figure (7): IPR Plot after Scale Removal for Well (B-20).

Results

From flow rate (qo) calculation of wells before and after we noted that:

1. Well B96 experienced production increase after the operation acid job 284BOPD, and therefore permeability around wellbore was increased.
2. Well B72 experienced production increase after the operation acid job 694BOPD, and therefore permeability damage was decreased.
3. water cut increase of wells B96 and B72 from 0.4 to 0.5 after operation acid job.

Conclusions

1. Prosper is one of the most common software for the petroleum industry. It can assist the production or reservoir engineer to predict tubing and pipeline hydraulics and temperatures with accuracy and speed.
2. Well B96 experienced production increase after operation acid job which increased permeability around wellbore proof of the existing permeability damage before improvement.
3. Well B72 after operation acid job experienced a slight improvement and after period there is decrease in production over the years because of other reasons.
4. Well B20 operation acid job led to a slight improvement and production increase.

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