Journal of Natural Gas Science and Engineering 33 (2016) 634–643

Contents lists available at ScienceDirect

Journal of Natural Gas Science and Engineering

journal homepage: www.elsevier.com/locate/jngse

Condensate blockage study in gas condensate reservoir

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A R T I C L E I N F O

Article history:
Received 11 February 2016
Received in revised form
11 April 2016
Accepted 16 May 2016
Available online 24 May 2016

Keywords:
Condensate
Gas condensate
Blockage
Skin
Pressure
Model

A B S T R A C T

The effect of condensate blockage on the pressure drop near the well bore has been studied. Two types of single well simulations have been conducted and pressure drop due to condensate blockage has been quantified based on variation of gas relative permeabilities in near well bore area. The relationship of condensate banking pressure drop, gas rate and reservoir quality has been presented. It is shown that for a poor reservoir quality, condensate blockage can increase the pressure drop up to 200% of the pressure drop in the tubing.

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1. Introduction

Gas condensate reservoir with a pressure higher than dew point represents a single phase fluid. But at certain condition of pressure and temperature, condensation starts and the reservoir hydrocarbon forms two phase. Inside the pressure profile of the reservoir, the largest drop occurs near the well bore area. Most likely, in this zone, the pressure falls below the dew point value and liquid saturation with heavy ends builds up (Hinchman and Barree, 1985; Imo-Jack, 2010; Lal, 2003).

By definition, a lean gas condensate below the dew point produces less than the 100 STB/MMSCF of liquid, while on the other hand the rich fluid generates typically more than 150 STB/MMSCF (Fan et al., 2005).

Condensate liquids which form through the reservoir have different mobility (ratio of relative permeability to viscosity) behaviour. In the zones far from the well bore vicinity, the liquid is immobile due to low saturation and capillary forces. In near well bore zone, liquid saturation is higher than critical value and mobility will increase. At this condition, gas and liquid will compete for flow toward the well and the relative permeability of each fluid plays an important role (Fig. 1) (Du et al., 2004; Gringarten et al., 2000).

Condensate banking or condensate blockages are the term which has been defined for decreasing the gas mobility due to liquid condensation. There are a lot of fields in the world which reservoir pressure has lower than dew point due to gas production and most of them have condensate blockage problem. In the Arun field, which was operated by Mobil, now ExxonMobil, the loss in some wells was greater than 50% (Afidick et al., 1994; Barnum et al., 1995; Silpngarmlers et al., 2005). Shell and Petroleum Development Oman reported a 67% productivity loss for wells in two fields. Fig. 2 depicts a schematic of productivity reduction due to condensate blockage (Smits et al., 2001).

There are various remedial actions to alleviate the pressure drop caused by gas condensate blockage. The condensate liquid is more

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http://dx.doi.org/10.1016/j.jngse.2016.05.048
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valuable than gas specifically in regions which are far from the gas transport systems. This price different causes the gas recycling process economical and effective to produce more liquid. Dry gas which is injected in the reservoir maintain the reservoir pressure higher than dew point and the heavy ends that are still in gas phase will be displaced out of the reservoir and are produced at surface. Another application of dry gas is to vaporize the condensate around a well and then produce it. Other technologies which mitigate the productivity reduction in gas condensate reservoirs are hydraulic fracturing in sandstone formation and acidizing in carbonate fields. Well trajectory is an effective way to increase contact area with formation by horizontal or slanted wells. Chemical or surfactant injection could be accounted as removal methods of condensate blockage by changing the wetability (Fan et al., 2005).

In this study, after literature review of existing analysis of condensate blockage effect, two types of single well simulations are presented and skin value and pressure drop of this phenomena are quantified. The data from a gas condensate field located in the Middle East suggests that most wells suffer from liquid saturation build up around the wellbore as depicted in Fig. 3.

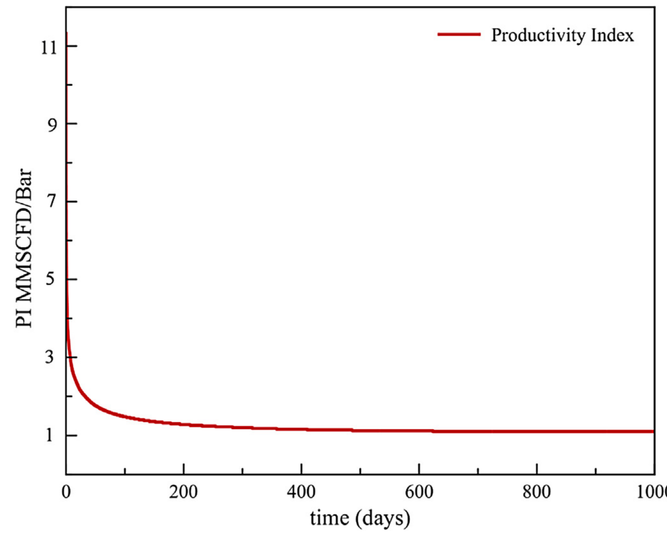

Fig. 2. Schematic of PI reduction.

2. Literature review

Kamath (Kamath, 2007) indicated five steps to study condensate blockage. It starts with laboratory measurements and covers fitting the experimental data, using the spreadsheet tools, single well modelling and finally full field simulations. It has been proposed to use hydraulic fracturing and chemical treatment to improve productivity index (Kamath, 2007). In other comprehensive study, gas condensate compositional analysis, developing the base case model and full field simulation have been carried out. It has been deducted that skin value related to condensate blockage will be overestimated in case of velocity dependent relative permeability ignorance in near well bore area (Seah et al., 2014).

A condensate banking analysis has been done in the North Belut field, located in the West Natuna Sea, Indonesia. The field property including permeability is low. This study included reservoir simulation along with experimental work on permeability. To incorporate the effects of condensate blockage in field simulation model, two strategies were proposed: Employ the skin factor or well grid cell relative permeability. Experimental work confirmed that gas relative permeability increases with capillary number (velocity). The final result of condensate blockage evaluation in North Belut field showed that the impairment is minor (Noor et al., 2005; Whitson et al., 2003).

Miller et al. studied the effect of horizontal well to improve well deliverability and reduce the condensate blockage skin in North field which adjoins Iran's South Pars field. Having simulated by the commercial reservoir simulator (Eclipse compositional simulator, E300), the draw down pressure in vertical wells is much higher than horizontal ones which causes the pressure falling below the dew point faster. Liquid saturation around the well is higher for vertical wells with lower PI (Denney, 2010; Miller, 2009; Whitson and Kuntadi, 2005). The relevant skin factor of condensate blockage effect was calculated by matching the field reservoir simulation to radial model. Including the capillary number effect in calculation makes the skin value reduction from 15 to 3. This range is not related to permeability distribution (Kuntadi, 2004).

One of the largest gas condensate fields in the world is Arun field which contains lean gas condensate fluid. Due to 10 years of production and pressure drop in the reservoir, well productivity index of most of the wells has been significantly reduced. Condensate blockage reported to play an important role for this reduction (Afidick et al., 1994; Narayanaswamy et al., 1999).

In Santa Barbara field, the biggest Venezuelan gas-condensate

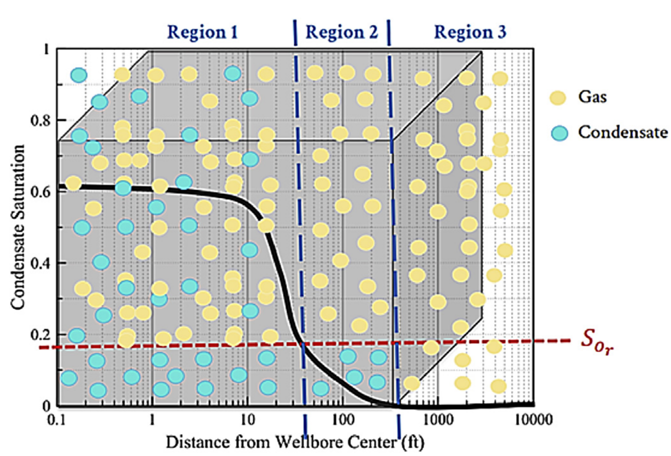

Fig. 1. Different regions of condensate drop out.

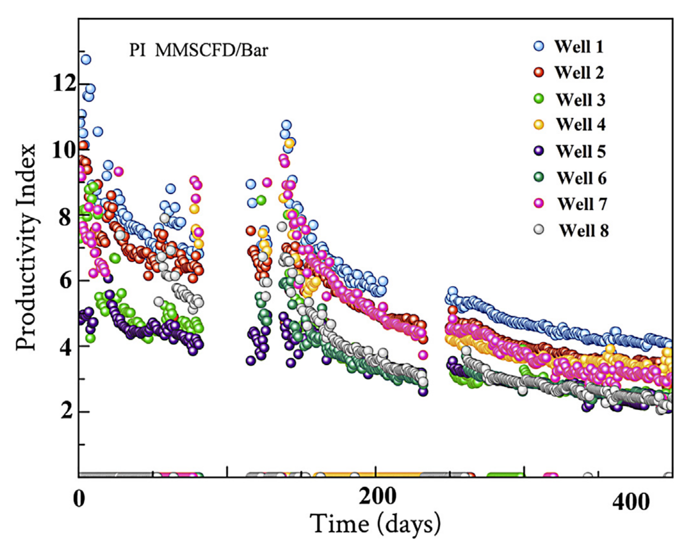

Fig. 3. Real well data of the gas condensate field – PI reduction.

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