# Understanding the Behaviors of Gas Condensate Reservoirs

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***Abstract*** ***- Well productivity estimation in gas condensate reservoirs is still a challenge. This is due to the complex compositional changes and phase behaviors which occur when wells are produced below the dew point. Various solutions have been implemented in order to remediate such a productivity loss. They include drilling horizontal wells instead of vertical wells, hydraulically fracturing vertical wells before or after the development of the condensate bank, and acidizing after the condensate bank has formed. The purpose of this research study is to investigate the effects of well and reservoir parameters on the time to reach abandonment conditions for both horizontal and vertical wells in volumetric retrograde gas-condensate reservoirs using three-dimensional, single-well compositional reservoir simulation model.***

***Key words:*** *Gas-condensate reservoirs, Hydrulic fracture, Vertical and horizontal wells, Eclipse 300 compositional simulator, Oil and recovery factors.*

## 1. INTRODUCTION

The decline of reservoir pressure below the dew-point pressure in retrograde gas-condensate reservoirs leads to the buildup of a liquid condensate phase in the reservoir, including the area near the wellbore, resulting in condensate blockage or condensate banking. To decrease or to postpone the adverse effect of condensate blockage on productivity, several methods have been suggested. One of these methods is the use of hydraulically fracturing vertical wells instead of vertical wells in order to reduce the effects of condensate blockage or condensate banking on productivity of wells.

Due to the composition and phase changes of light components that occur during reservoir depletion, there is a great need for a quick and reliable method or models to estimate the horizontal and vertical wells performance in retrograde gas-condensate reservoirs. In addition, quantifying the effects of well and reservoir parameters on the performance of horizontal and vertical wells in gas condensate reservoirs is very important to decide what type well to utilize in a given reservoir.

Predicting the effects of reservoir and well parameters on the performance of horizontal and vertical wells in retrograde gas-condensate reservoirs is important in determining the well type needed in a given formation. Due to increased number of horizontal wells drilled in retrograde gas-condensate reservoirs, there is a necessity for better and improved understanding of the behavior and performance of this type of wells in retrograde gas-condensate reservoirs.

## 2. LITERATURE REVIEW

Several studies have examined the various factors that influence the behavior of retrograde gas-condensate reservoirs. There are also several reservoir simulation studies on the performance of vertical wells in gas-condensate reservoirs. Moreover, numerous authors have investigated the phenomenon of a rapid loss of productivity of vertical wells in retrograde gas-condensate wells such as [1, 2, 3, 4, 5, 6, 7, and 8 ].

## 3. RESEARCH METHODOLOGY

To simulate the depletion processes, the Eclipse 300 compositional simulator was used to investigate the effects of the effect of hydraulic fracture on the performance of a rich gas condensate reservoir. A simulator is a program used to perform material balance calculations to determine pressure and saturation distribution of the reservoir as a function of time. Reservoir simulation models are commonly used to predict the performance of retrograde gas-condensate reservoirs. The models incorporate rock and fluid properties and are used to predict the dynamic influence of condensate blockage on gas and condensate production.

A compositional reservoir simulator is also used to model the complex compositional changes and phase behavior which occurs in retrograde gas-condensate reservoirs during production. The compositional simulation models assume that reservoir fluid properties are dependent not only upon the reservoir temperature and pressure but also on the composition of the reservoir fluid which changes during production, either by depletion or by gas injection.

### 3.1 Reservoir and fluids Models Description

In this study we used a synthetic reservoir model that includes the fluid description of a real gas condensate. This synthetic reservoir model of a single layer homogenous reservoir was generated. The fluid selected for our study is a very rich gas condensate taken from Cusiana Field located 125 miles northeast of Bogotá, Colombia. Data was taken from [9 and 10]. The simulation synthetic reservoir model used in this study consisted of a single layer homogenous reservoir with a drainage area of 160 acres, formation thicknesses of 25, 50 and 100 ft, 20% porosity, and three horizontal permeabilities: 1, 10 and 100 md were considered. Vertical to horizontal permeability ratio ($k_v/k_h$) of 0.1, 0.5 and were considered. The top of the model is at a depth of 12000 ft with an initial pressure of 5868 psia.

### 3.2 Well Model Description

Two well models were developed for this study; a vertical well model and a horizontal well model as shown in Figures 1 and 2. The vertical well was modeled in radial and Cartesian coordinates while the horizontal well was modeled in Cartesian coordinates.

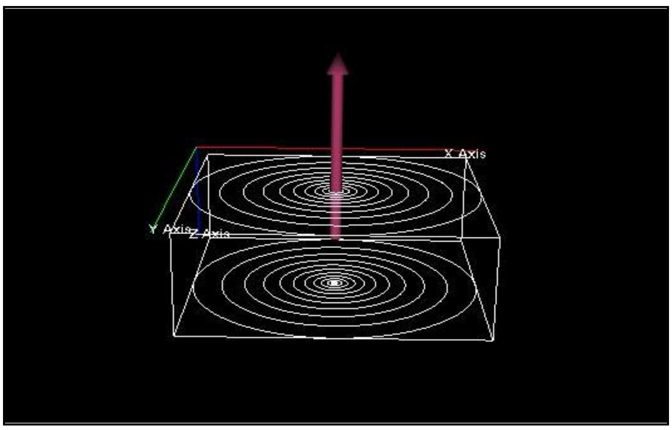


**Fig. - 1:** Schematic vertical well model

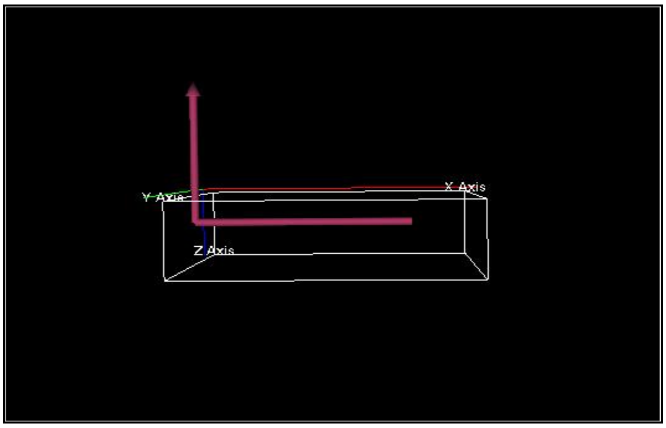


**Fig. - 2:** Schematic horizontal well model

## 4. RESULTS AND DISCUSSION

In this research study, several simulation runs were made in order to investigate the effects of well and reservoir parameters on the the time to reach abandonment conditions for both horizontal and vertical wells in retrograde gas-condensate reservoirs. An attempt will be made to obtain a relationship between well and reservoir parameters and the time to reach abandonment conditions for both horizontal and vertical wells. In this research, the abandonment condition for both horizontal and vertical wells is reached when the well production rate becomes less than 100 MSCF/D for a bottom-hole flowing pressure of 700 psia.

Various attempts to develop reliable graphical form were made and it was determined that the time to reach abandonment conditions correlates very well with formation thickness in a given reservoir for both vertical wells and horizontal wells of a given penetration ratio, as shown in Figures 3 through 9. Figures 3 through 8 are for horizontal wells located in a 160-acre, square drainage area with horizontal permeabilities of 1, 10, and 100 md for $k_v/k_h$ values of 1, 0.5 and 0.1. Figure 9 shows the results for the vertical wells located in the same reservoirs. Free gas and oil recovery factors relationships as a function of horizontal wellbore lengths are shown in Figures 10 and 11. While Figures 12 and 13 show oil distribution map for a horizontal well located in a 160-acres square drainage area, with a formation thickness of 100 feet, horizontal permeability of 100 md, horizontal penetration ratio of 0.8, and $k_v/k_h$ value of 1.

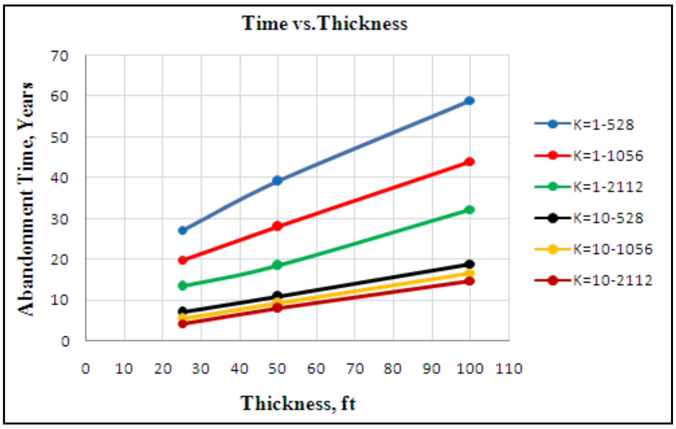


**Fig. -3:** Abandonment time prediction for horizontal wells as a function of thickness by this work at A = 160 acres, square drainage area, k =1 and 10 md, and $k_v/k_h$ = 1

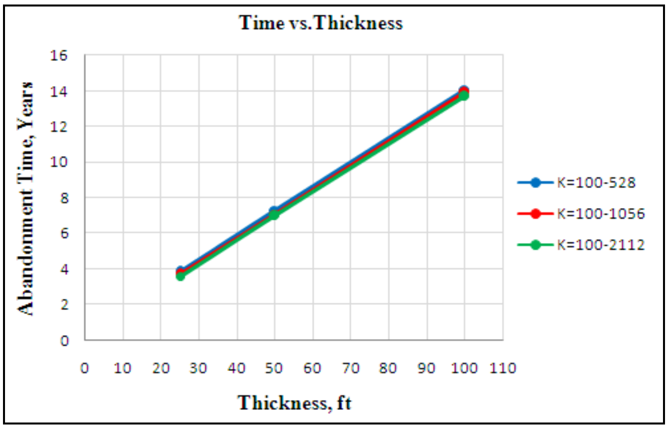


**Fig. - 4:** Abandonment time prediction for horizontal wells as a function of thickness by this work at A = 160 acres, square drainage area, k = 100 md and $k_v/k_h$ = 1

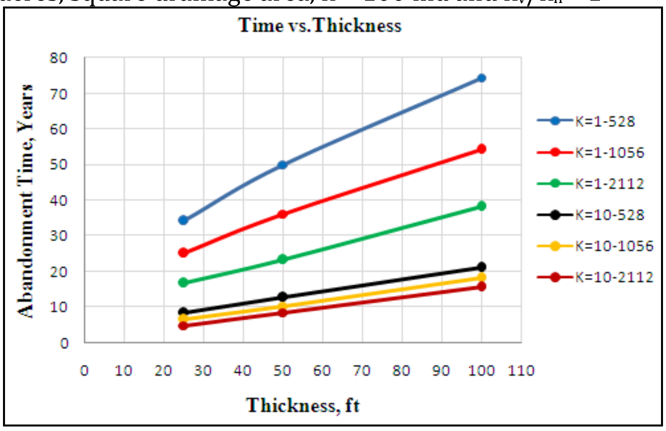


**Fig. -5:** Abandonment time prediction for horizontal wells as a function of thickness by this work at A = 160 acres, square drainage area, k =1 and 10 md and $k_v/k_h$ = 0.5

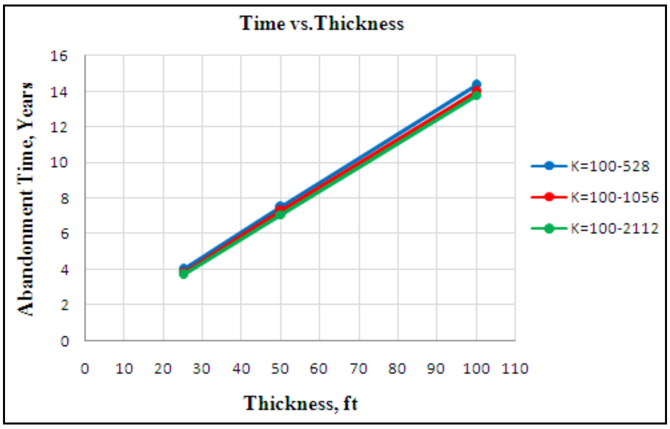


**Fig. - 6:** Abandonment time prediction for horizontal wells as a function of thickness by this work at A = 160 acres, square drainage area, k = 100 md and $k_v/k_h$ = 0.5

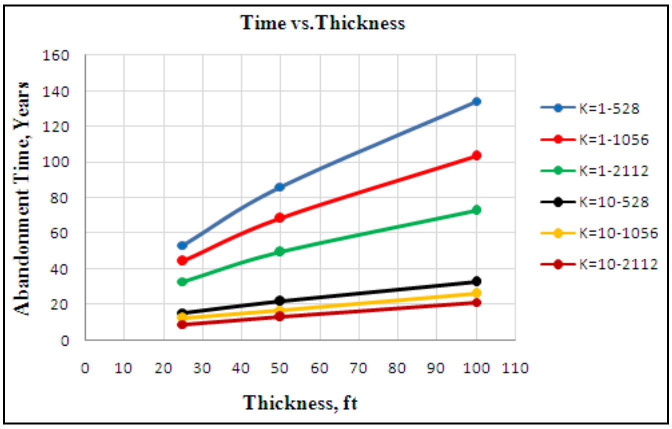


**Fig. - 7:** Abandonment time prediction for horizontal wells as a function of thickness by this work at A = 160 acres, square drainage area, k = 1 and 10 md and $k_v/k_h$ = 0.1

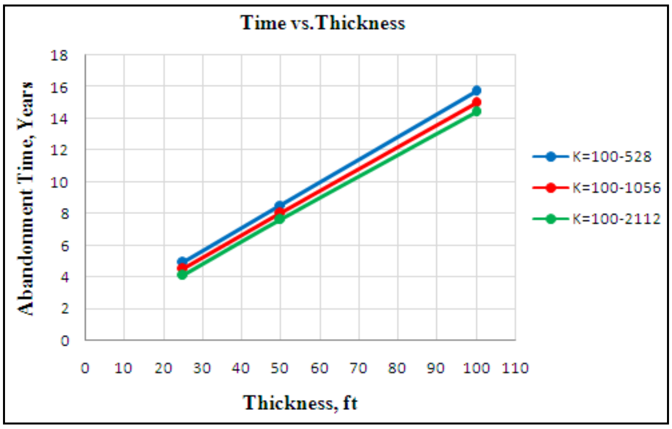


**Fig. - 8:** Abandonment time prediction for horizontal wells as a function of thickness by this work at A = 160 acres, square drainage area, k = 100 md and $k_v/k_h$ = 0.1

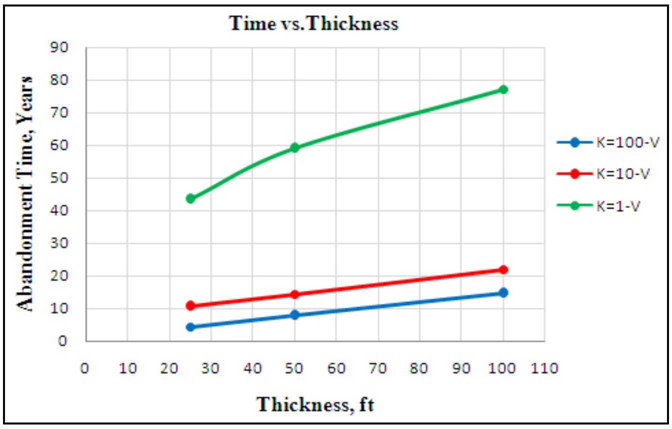


**Fig. - 9:** Abandonment time prediction for vertical wells as a function of thickness by this work at A = 160 acres, square drainage area

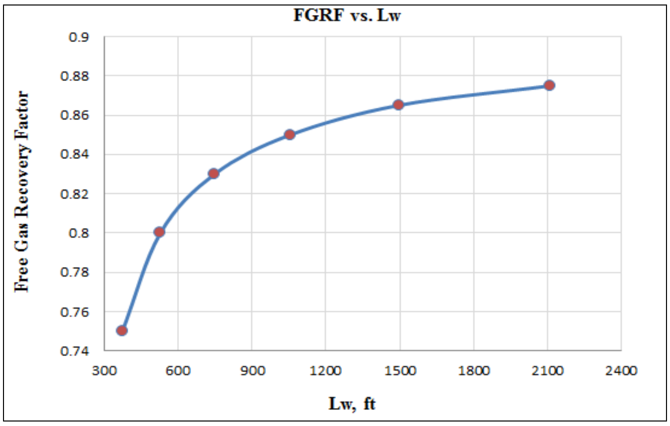


**Fig. - 10:** Free gas recovery factor prediction for horizontal well as a function of horizontal wellbore lengths by this work at h = 100 ft and k = 100 md

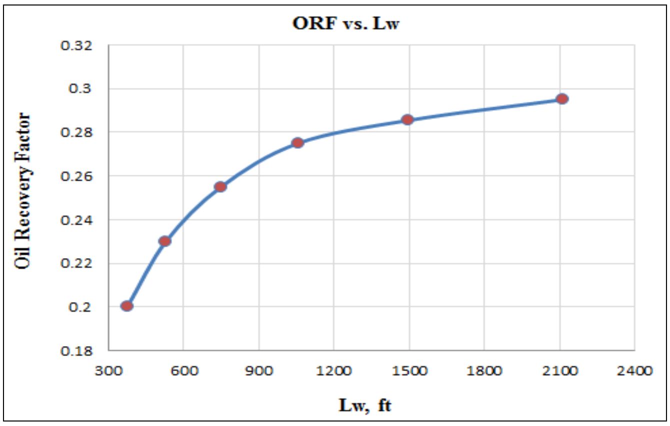


**Fig. - 11:** Oil recovery factor prediction for horizontal well as a function of horizontal wellbore lengths by this work at h = 100 ft and k = 100 md

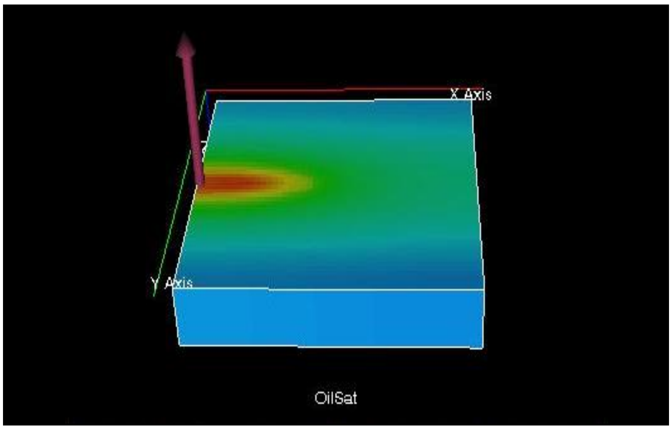


**Fig. - 12:** Oil distribution map for horizontal well at A = 160 acres, square drainage area, h = 100 ft, k =100 md, $L_H$ = 2112 ft and $k_v/k_h$ = 1

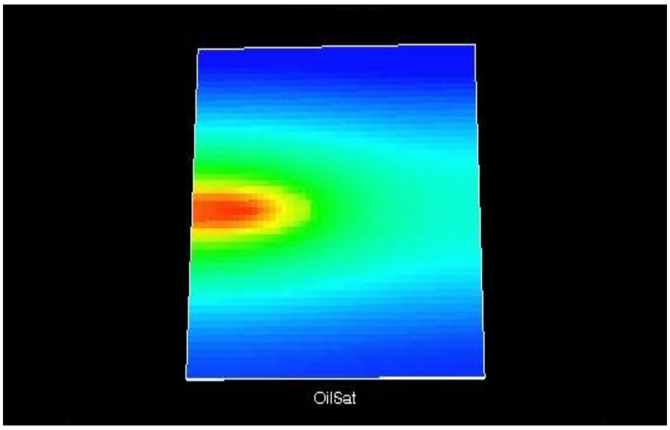


**Fig. - 13:** Oil distribution map for horizontal well at A=160 acres, square drainage area, h = 100 ft, k = 100md, $L_H$ = 2112 ft and $k_v/k_h$ =1

## 5. CONCLUSIONS

Based on the analysis of the results obtained in this research study, the following conclusions can be made with regards to the effects of well and reservoir parameters on the time to reach abandonment conditions for both horizontal and vertical wells in volumetric retrograde gas-condensate reservoirs.

- This is the first time such graphical form correlations have been obtained for determining the time to reach abandonment conditions.
- These results show that doubling the formation thickness (i.e., doubling the reservoir volume) does not double the time to reach abandonment conditions; in other words, it does not double the time to produce the recoverable reserves.

- For a horizontal permeability of 100 md and ratio of vertical to horizontal permeability of 1, there is no effect of well and reservoir parameters on the time to reach abandonment conditions.
- For a horizontal permeability of 100 md and ratio of vertical to horizontal permeability of 0.5, there is a slight effect of well and reservoir parameters on the time to reach abandonment conditions.
- When the reservoir pressure drops below the dew-point pressure, significant condensate saturation builds up around the wellbore.

## NOMENCLATURE

| | |
|---|---|
| A | Drainage area, acres |
| h | Reservoir thickness, ft |
| H | Horizontal well |
| K | Horizontal permeability, md |
| $K_v$ | Vertical permeability, md |
| $L_H$ | Length for a horizontal well, ft |
| t | Abandonment time |
| V | Vertical wells |
| ORF | Oil recovery factor |
| FGRF | Free gas recovery factor |

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## BIOGRAPHIES

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