Simple scaling theory used to better predict gas production in barnett shale wells

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Researchers at The University of Texas at Austin have developed a simple scaling theory to estimate gas production from hydraulically fractured wells in the Barnett Shale. The method is intended to help the energy industry accurately identify low- and high-producing horizontal wells, as well as accurately predict how long it will take for gas reserves to deplete in the wells.

Using historical data from horizontal wells in the Barnett Shale formation in North Texas, Tad Patzek, professor and chair in the Department of Petroleum and Geosystems Engineering in the Cockrell School of Engineering; Michael Marder, professor of physics in the College of Natural Sciences; and Frank Male, a graduate student in physics, used a simple physics theory to model the rate at which production from the wells declines over time, known as the "decline curve."

They describe their new model of the decline curve in the paper "Gas production in the Barnett Shale obeys a simple scaling theory," published this week in the *Proceedings of the National Academy of Sciences*. To test their theory, the researchers analyzed 10 years of gas production data from the Barnett Shale licensed to the university by IHS CERA, a provider of global market and economic information.

The team's estimates were an instrumental part of the comprehensive assessment of Barnett Shale reserves funded by the Alfred P. Sloan Foundation and issued earlier this year by the Bureau of Economic

Geology at UT Austin.

Until now, estimates of shale gas production have primarily relied on models established for conventional oil and gas wells, which behave differently from the horizontal wells in gas-rich shales.

The researchers estimate the ultimate gas recovery from a sample of 8,294 horizontal wells in the Barnett Shale will be between 10 trillion and 20 trillion standard cubic feet (scf) during the lifetime of the wells. The study's well sample is made up of about half of the 15,000 existing wells in the Barnett Shale, the geological formation outside Fort Worth that offers the longest production history for hydrofractured horizontal wells in the world.

"With our model at hand, you can better predict how much gas volume is left and how long it will take until that volume will be depleted," Patzek said. "We are able to match historical production and predict future production of thousands of horizontal gas wells using this scaling theory."

"The contributions of shale gas to the U.S. economy are so enormous that even small corrections to production estimates are of great practical significance," Patzek said.

The researchers were surprised by how all of the wells they analyzed adhere to that simple scaling curve.

"By analyzing the basic physics underlying gas recovery from hydrofractured wells, we calculated a single curve that should describe how much gas comes out over time, and we showed that production from thousands of wells follows this curve," Marder said.

Patzek adds: "We are able to predict when the decline will begin. Once decline sets in, gas production goes down rapidly."

The decline of a well happens because of a process called pressure diffusion that causes pressure around a well to drop and gas production to decrease. The time at which gas pressure drops below its initial value everywhere in the rock between hydrofractures is called its interference time. On average, it takes five years for interference to occur, at which point wells produce gas at a far lower rate because the amount of gas coming out over time is proportional to the amount of gas remaining.

Using two parameters—a well's interference time and the original gas in place—the researchers were able to determine the universal decline curve and extrapolate total gas production over time.

The researchers found that the scaling theory accurately predicted the behavior of approximately 2,000 wells in which production had begun to decrease exponentially within the past 10 years. The remaining wells were too young for the model to predict when decreases would set in, but the model enabled the researchers to estimate upper and lower production limits for well lifetime and the amount of gas that will be produced by the wells.

"For 2,057 of the horizontal wells in the Barnett Shale, interference is far enough advanced for us to verify that wells behave as predicted by the scaling form," Patzek said. "The production forecasts will become more accurate as more production data becomes available."

As a byproduct of their analysis, the researchers found that most horizontal wells for which predictions are possible underperform their theoretical production limits. The researchers have reached a tentative conclusion that many wells are on track to produce only about 10 percent of their potential.

The researchers conclude that well production could be greatly improved if the hydrofractures connected better to natural fractures in the surrounding rock. The process of hydraulic fracturing creates a network of cracks, like veins, in rocks that was previously impermeable, allowing gas to move. If there are high porosity and permeability within those connected cracks and hydrofractures, then a well is high producing. By contrast, if the connection with hydrofractures is weak, then a well is low producing.

"If this finding spurs research to understand why wells underperform, it may lead to improved production methods and eventually increase gas extraction from wells," Marder said.

Work is underway on how to improve performance of hydrofractures in horizontal wells, Patzek added.

More information: Gas production in the Barnett Shale obeys a simple scaling theory, www.pnas.org/cgi/doi/10.1073/pnas.1313380110

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