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Novel well test design for the evaluation of complete well permeability and productivity for CSG wells in the Surat Basin

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ABSTRACT

The Surat Basin Coal Seam Gas (CSG) play requires a vast number of wells to develop, and reservoir productivity changes quickly over small distances. Well testing provides a means to evaluate these changes. The high cost of conventional testing precludes sufficient tests to ensure areal and statistical coverage across a large well stock. This paper discusses a new approach, with a reduced cost, that allows five times more wells to be tested than conventional methods. By testing more wells, there is more data for subsurface model calibration and productivity fairways can be better mapped and developed.

In the Surat Basin CSG play there is an industry-wide completion technique that uses air to lift every well to size the initial downhole pump for dewatering. This paper describes an enhancement to this standard pump sizing test which facilitates the provision of key reservoir information: full well permeability, skin and productivity. This novel well test is termed an Air Assisted Flow Test (AAFT).

During the AAFT the well is produced at a predictable drawdown for up to an hour whilst accurate rate measurements are made at surface. A downhole shut-in is then performed and a pressure gauge measures the build-up pressure response. The additional equipment and rig time have been designed to add a minimal cost to the standard completion operation and test cost is 20% of a traditional Drill Stem Test (DST).

Field tests using the AAFT and multiple dual packer DST's in the same well clearly demonstrate that both testing methodologies deliver the same results. It is therefore valid to incorporate the AAFT into the extensive permeability database for the Surat Basin. Additionally drawdown dependent skin has been observed in data from the new AAFT. This phenomenon is interpreted to be the result of stress dependent coal fracture permeability in the near well bore region.

This new testing method is only directly relevant to CSG developments. However the awareness to gather additional data, from enhancing a standard operation, is applicable to all unconventional and conventional reservoirs.

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1. Introduction

As of mid-June 2015 QGC has drilled over 2500 CSG production wells in the Surat Basin on a 750 m (140 acre) spacing. Each of these wells has been, or will be, lifted with air to get a base water rate to size the initial downhole pump for de-watering. This complete data set, i.e. one water rate per well, is challenging to incorporate into subsurface models. Furthermore, there are uncertainties in the water rate measurement and the flowing bottom hole pressure (FBHP) is not known. This simple pump sizing test was enhanced to the Air Assisted Flow Test (AAFT) to give results that are direct inputs into subsurface models; full well permeability, skin and productivity.

Of the 2500 production wells around 350 wells have had dual packer tests performed on them to collect permeability data. These dual packer tests are either Drill Stem Tests (DST), or are performed

Abbreviations: AAFT, Air Assisted Flow Test; CSG, Coal Seam Gas (Coal Bed Methane); DST, Drill Stem Test; FBHP, Flowing Bottom Hole Pressure; FRT, Repeat Formation Tester, Weatherford; IARF, Infinite Acting Radial Flow; IPR, Inflow Performance Relationship; Kh, Permeability Thickness (millidarcy meters, mD m); MDT, Modular Dynamic Tester, Schlumberger; PTA, Pressure Transient Analysis.

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on wireline with the Modular Dynamic Tester (MDT) or the Repeat Formation Tester (FRT). Generally 3–5 intervals are tested per well, with gross interval thickness of 8–20 m. Two packers are inflated around the interval and flows and build ups are performed to produce data for Pressure Transient Analysis (PTA) (Kabir et al., 2011).

The dual packer tests with 3–5 intervals per well only covers around 30% of the net coal in a well. This leaves uncertainty as to how the remaining 70% of the net coal will behave. The new AAFT captures 100% of the net coal. An additional benefit of the AAFT over the conventional dual packer tests is cost effectiveness. Five wells can be tested by AAFT for the same cost of one well using dual packer tests.

Productivity can change dramatically over the 750 m between wells. Productive areas are located on fairways where coal permeability is high. Well testing provides a method to find these fairways and map their edges. The AAFT is a more useful tool than dual packer tests when searching for productivity fairways, because more coal is tested per well and more wells are tested. This gives better resolution of fairway limits and allows maximisation of the productive well count while reducing the numbers of wells drilled off the fairway.

The disadvantage of the AAFT is that there is no vertical (zonal) resolution; the whole well is flowed and contributions from producing coals are commingled. A trial to get zonal allocation during an AAFT using a Distributed Temperature Sensing (DTS) installation was performed (Furniss et al., 2014). But the temporary installation removed the cost advantage of the AAFT and therefore DTS-based zonal allocation is only applicable for a selected number of long-term installations. In contrast, during dual packer testing, intervals are tested separately, providing reservoir properties for defined zones of producing coals. The subsurface model needs to account for the high degree of vertical heterogeneity between coals; therefore to populate it with permeability data AAFT results require calibration to dual packer tests.

1.1. Walloon coal measures

The Walloon Subgroup in the Surat Basin contains a world class CSG play. CSG development areas are reasonably shallow at 100–1000 m below ground level and produce from moderate rank, sub-bituminous coals. The gross zone of commercial interest is typically 300–450 m thick (Martin et al., 2013) and comprises 10% net coal (~30 m in total). Coal seams are generally thin (mean thickness: 30 cm) and are interbedded with low permeability clastic rocks. Coal fracture permeability varies considerably from <0.1mD to >1000mD with virgin reservoir pressures being close to hydrostatic.

2. Materials and methods: developing the Air Assisted Flow Test

The simple pump sizing test that occurs on every well is performed by a completion rig. A drilling Bottom Hole Assembly (BHA) is run on tubing to well Total Depth (TD), then air is injected through the bit lifting the well fluids up the annulus and this water rate is measured for one hour. The measured rates are averaged and reported. Compressed air is provided by two 'air packs' that are capable of large air injection rates between 900 and 2600 cubic feet per minute (cfm). There is no measure of downhole pressure and drawdowns can vary enormously well to well. This is due to: variations in the depth of air injection (300–1000 m below ground level), different rigs using different numbers, type and settings on the air packs and variations in produced water rates (100–9000 barrels per day (bpd)).

To enhance this simple flow rate test to give permeability, skin and productivity data three key areas had to be addressed: improve the accuracy of the water rate measurement, control flowing bottom hole pressure and perform a shut-in with a pressure build-up for Pressure Transient Analysis (PTA).

2.1. Water rate

The simple pump sizing test is used to size a Progressing Cavity Pump (PCP) which has a relatively good turndown range, i.e. one pump can produce over a large range of water rates. Therefore it is not critical to measure precise values of water rate. However, to perform PTA based on AAFT data a precise rate is needed since the water production rate is directly related to the permeability outcome.

During the pump sizing test the water rate is measured by the use of a V-Weir. The well flows into an open tank where the only exit is through a V notch cut into the side wall, the V-Weir is shown in Fig. 1. The V-Weir is graduated allowing constant monitoring of the water rate flowing back from the well.

The water rate is taken visually and averaged for the one hour flow test, this human element introduces error. It has been observed that many wells have identical water rates recorded. These identical rates all corresponded to the labelled scale on the V-Weir, a human bias is introduced by selecting the labelled graduations. The true water production rates for these wells will be different. This outcome is acceptable when sizing a flexible downhole pump, but when calculating rate for PTA greater accuracy is required.

Therefore a number of automated water meters were trialed to remove operator bias. The final solution was to attach a radar unit to the top of the tank which measures the fluid height in the tank with greater accuracy, resolution and frequency to those recorded by field operators, as seen in Fig. 2.

2.2. Drawdown control

For the simple pump sizing test air is injected at the bottom of the well, this imparts a large and uncontrolled drawdown on the well. To manage the drawdown during the AAFT the depth of air injection is controlled. This is achieved by running a perforated pup in the tubing string. By increasing the depth of the perforated pup increased drawdowns can be achieved, as seen in Fig. 3. Pressure gauges and an Electro Magnetic (EM) telemetry system are run below the perforated pup to monitor drawdown and build-up pressures. The EM telemetry system allows the test to be modified at surface during operations. Specific drawdowns can be targeted by changing the depth of lifting (perforated pup depth). Flow and shut-in period length can be shortened or extended given the real time data so a complete data set can be captured.

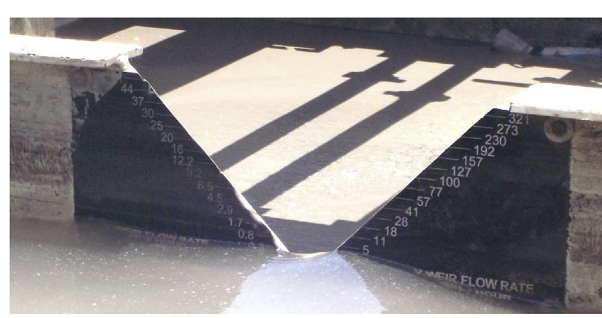

Fig. 1. ARC's V-Weir on the flow back tank (SCUF tank). Fluid levels higher up the V-Weir correspond to higher flow rates from the well. The scale on the right hand side of the plate is in barrels per hour.

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