Optimizing Multizone Coalbed Methane Well Completions

CASE STUDY 08-03

A GAS SENSING TECHNOLOGY CORP. SUCCESS STORY

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Challenge

Multizone completions are attractive options for extending and/or increasing existing production from declining wells via re-entry of additional zones. Determining which available seams should be completed and which should be by-passed is both key to success and difficult to achieve. This research study illustrates how the challenges encountered when completing coalbed methane wells in multiple formations can be surmounted by deliberate use of reservoir analysis tools.

Solution

GST WellDog's spectroscopic reservoir analysis was utilized to determine Critical Desorption Pressure (CDP), Gas Content (GC), and percent saturation on 27 seams in twelve wells, nine of which were multi-seam completions, each with up to three seams identified as potential producing target zones picked from the available gamma ray log. This information was used, along with other reservoir parameters, to compare each coal seam's contribution towards overall water and gas production.

Results

As is always the case in coalbed methane development, coalbed reservoir heterogeneity is high not only between seams, but across continuous portions of seams. This result demonstrates that more detailed analysis of coalbed methane reservoirs is required in order to increase development success. Without the GST WellDog technology, the reservoir analysis portion of this study would have required more than $750,000 and up to eight months of field- and lab-work. Using the WellDog technology, it required less than $200,000 and less than two weeks of field- and lab-work.

Completing Coalbed Methane Wells in Multiple Formations

The Powder River Basin, located in northeast Wyoming, and southeast Montana, has been the location of the nation's fastest growing development of coal bed natural gas (CBNG). Production of CBNG, to date, from the tertiary-age Fort Union Formation has been in the east and central portion of the basin, near Gillette, Wyoming, with recent development efforts targeting the deeper basin center. Of the 17,000 CBNG wells in the PRB, over 9,600 produce less than 30 mcf/day. CBNG operators in the PRB are now attempting to implement multizone completions, since they are experiencing a low success rate using the current practice of single-seam completions (while bypassing several thinner seams). While multizone completions should enhance economic gas production, reservoir conditions in the PRB, which tend to be shallow, undersaturated coals of highly variable critical desorption pressure (CDP) and gas content (GC) surrounded by water-bearing aquifers, have not proven suitable for multizone completions. To date, results from multizone completions have not been widely favorable.

The study was part of a research effort funded by the Department of Energy to develop a "Best Practices Guide to Optimizing Multi-zone Coalbed Natural Gas Well Completions." The project involved mapping the key reservoir properties that determine future production from all seams, using those properties to inform development, producing water and gas from the mapped reservoirs, and correlating the reservoir properties to the resulting production. This final correlation was then used to establish how reservoir testing can inform production success and operator cash flow, particularly when applied to multizone completions. The work on this study was done in conjunction with Black Diamond Energy Inc. on their existing leases in the Powder River Basin (T52N R77W, Sec. 20, Johnson County, Wyoming).

Finding the Gas

GST WellDog used its proprietary geochemical reservoir analysis technology to measure critical desorption pressure (CDP), gas content (GC) and gas saturation in several coal seam reservoirs intersected by a dozen coalbed methane (CBM) wells on nine of which were multi-seam completions, each with up to three seams identified as potential producing target zones picked from the available gamma ray logs.

The coalbeds are interspersed with sandstone, conglomerate, siltstone, mudstone, shale, and limited thinly laminated limestone beds. Most coalbed methane (CBM) wells in the Powder River Basin target coals in the Wyodak-Anderson coal zone in the Tongue River Member of the Fort Union Formation. This coal zone is also called the Wyodak or the Anderson, and it can be subdivided further into the Smith, Anderson, Big George, Canyon, and Cook coals. All of these coalbeds are coalbed methane targets, along with the Wall coal located stratigraphically below the Wyodak-Anderson coal zone. Due to lateral discontinuity of these coalbeds and the lack of a standardized nomenclature for CBM operators, the target coals for many CBM wells have been mislabeled.

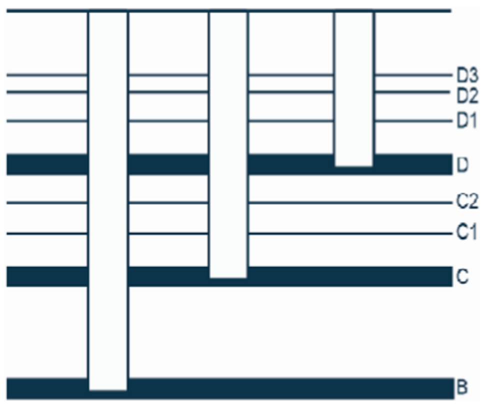

Figure 1 (Left) is a diagram of the three well pod structure used in this study. The study area was focused on four well pads that straddle the Powder River. Each well pad included three wells that were completed initially in three different coals the Anderson, the Cook and the Wall seams (Figure 1 above). Above each of the Anderson and the Cook seams were present up to three stringers of the base coal seams. The four well pads in Section 20 were configured in a diamond pattern.

GST WellDog performed standard Critical Gas Content downhole logs of solution gas during each well test. In these tests, WellDog measured solution gas concentration, as well as reservoir temperature, pressure and salinity. The reservoir properties are used to calculate an appropriate solubility constant for methane in water. The concentration is used, together with that solubility constant, to calculate the partial pressure (or CDP) of methane in the reservoir. That partial pressure is then used, together with an adsorption isotherm for the coal of interest, to calculate a gas content value.

GST WellDog performed 15 tests of isolated coalbed reservoirs in the 12 wells, plus five tests of commingled reservoirs in those wells. 12 of the tests provided data that could be attributed directly to an individual reservoir. Those tests revealed that, contrary to conventional wisdom, the more shallow Cook and Anderson coal seams contained more gas and less water than the deeper Wall seam. In addition, the tests revealed that critical desorption pressure and gas content varied to a surprisingly high extent between coal seams and, within each coal seam, between well pads.

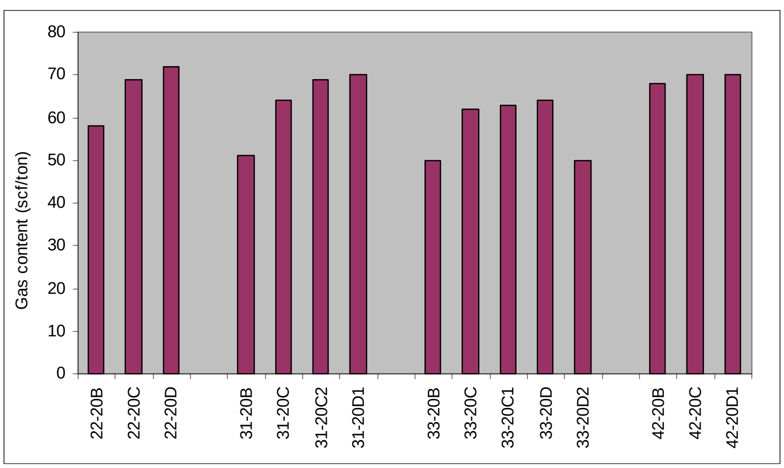

Figure 2. Plot of gas content by well pad

The operator (Black Diamond Energy) was able to produce eight of the wells for a brief period of time. While that production data proved insufficient for correlation with the reservoir data, additional production data from surrounding leases was obtained and used, as well. In general, offset production confirmed the reservoir testing results: wells completed in the Anderson seam showed a much lower water/gas production ratio than those completed in the Wall seam.

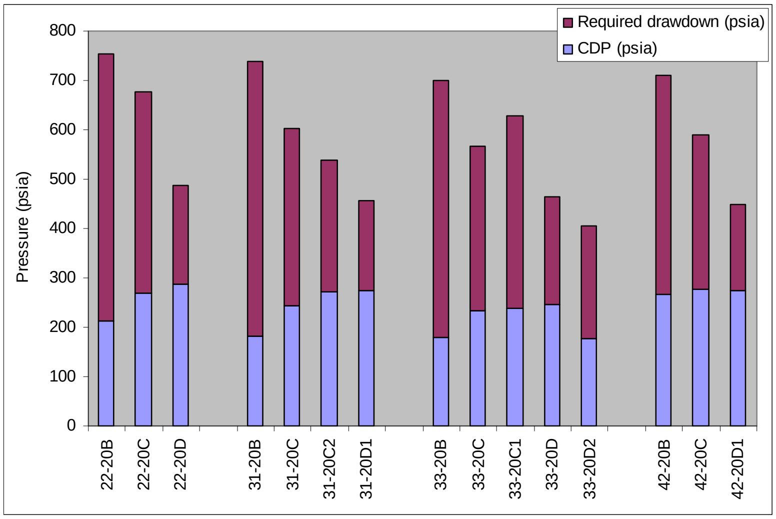

Figure 3 – Plot of critical desorption pressure and required drawdown by well pad

Interpretation of Gas Production Potential

Trends in the reservoir analysis data can be examined to assist in making lucid completion and production decisions. In general, geologists assume that deeper coal seams contain more gas – due to their greater rank/maturity, the higher hydrologic pressures typically available in deep coal seams so that more gas is capped, and general industry experience. However, in this study the coal seam reservoirs exhibited properties that ran directly against this conventional wisdom. Remarkably, gas content was inversely proportional to seam depth (with one exception). The deeper Wall coal did not show substantially higher gas content or critical desorption pressure, on average, than the more shallow Anderson coal, as might be expected from normal coalbed reservoir assumptions. In fact, the Wall coal showed lower gas content on average – 57 scf/ton – than either the Cook (66 scf/ton average) or the Anderson (64 scf/ton average) coals.

When this trend is combined with the lower porosity/permeability of the Wall coal, and the higher hydrostatic pressure measured for the deeper Wall coal, the result is that the Wall coal might not be the highest priority completion target in this area. (In fact, the study results convinced the operator not to complete further wells in the B (Wall) seam in this area.) Unfortunately, the thickness of the Wall seam in this area is such that the amount of stranded gas-in-place is substantial – more than any other single seam/stringer tested.

Alternately, the D (Anderson) seam showed both a higher average CDP than the B (Wall) seam and a lower hydrostatic head than either the B (Wall) or C (Cook) seams. As a result, the gas in the D (Anderson) seam was judged the most producible of those evaluated.

Another conventional wisdom involves the belief that thick, continuous coal seams show homogenous, continuous levels of methane gas. This wisdom likewise is belied by the results of this study. For example, the gas content measured in each seam varied substantially across this very small field: from 50 scf/ton to 68 scf/ton for the B (Wall) coal, and even more – from 50 scf/ton to 72 scf/ton – for the D (Anderson) coal.

Surprisingly, CDP and gas content varied substantially even between stringers of the same seam. For example, in the 33-20 well, the gas content of the D seam was 64 scf/ton while the gas content of the D2 stringer was just 50 scf/ton.

Key Parameters For Economic and Production Evalutaion

Another way to assess producibility is to calculate the likely water/gas production ratio using gas-in-place and water-in-place models for each seam. Table 1 lists such calculations for the seams tested in the study. Totals for each package of seams is at the bottom.

Coal seam	GIP (MMCF)	WIP (BBLS)	Water/gas (BBLS/MCF)	Gas value ($3/MCF)	Water handling cost ($0.30/BBL)
Smith	2,027	1,466,545	0.72	$ 6,080,730	$ 439,964
D2	292	335,442	1.15	$ 876,570	$ 100,632
D1	522	433,902	0.83	$ 1,564,740	$ 130,171
D	985	840,149	0.85	$ 2,955,120	$ 252,045
C2	363	443,691	1.22	$ 1,088,040	$ 133,107
C1	544	655,522	1.21	$ 1,630,800	$ 196,657
C	934	1,194,002	1.28	$ 2,800,680	$ 358,200
B	1,429	9,352,501	6.54	$ 4,287,000	$ 2,805,750
Total, all seams	7,095	14,721,753	2.08	$ 21,283,680	$ 4,416,526
D Total	2,038	1,609,492	0.79	$ 6,112,920	$ 482,848
C Total	1,440	4,402,969	3.06	$ 4,319,490	$ 1,320,891
B Total	1,429	9,352,501	6.54	$ 4,287,000	$ 2,805,750

Table 1 – Distribution of water and gas volumes and costs throughout the coal seam reservoirs tested

Table 1 highlights the poor producibility of the B (Wall) seam. Multizone wells completed into all zones, as is typical, would show substantial water contributions from the B (Wall) zone. Those contributions would increase the time to gas, increase the water/gas production ratio, and increase water disposal costs for such multizone wells. In fact, the bulk of the total water disposal costs, listed at the right of the table, projected for all the seams originate from the B (Wall) zone.

While production data gathered from the wells tested are insufficient to correlate with the water/gas production predictions, a correlating trend has been observed in offset well production. For example, production by offset wells completed in the D (Anderson) zone by Pennaco/Marathon have shown a combined water/gas production ratio of 3.0 while that for wells completed in the B (Wall) zone have shown a combined water/gas production ratio of 2,127.

Study Conclusions

The results of the study show that success in multizone completions is determined not by the number of zones completed but instead by the production quality of the zones completed. Avoiding zones that contribute more water than gas under normal production scenarios, like the Wall zone in this area, can result in substantially higher gas production rates and lower water/gas production ratios for multizone completions.

Unfortunately, identifying contributing zones vs. non-contributing zones cannot be done based on depth, geology or volumetric analyses. In this study, the deepest and thickest zone, the Wall, shows both the lowest gas content and the highest water content. Conversely, the Anderson, the shallowest seam analyzed, showed high gas content and low water content, making it an ideal production target.

As is always the case in coalbed methane development, coalbed reservoir heterogeneity is high not only between seams, but across continuous portions of seams. For example, variations of gas content from 50 to 72 scf/ton were observed across the sample area of less than 200 acres. This result demonstrates that more detailed analysis of coalbed methane reservoirs is required in order to increase development success.

Without the WellDog technology, the reservoir analysis portion of this study would have required more than $750,000 and up to eight months of field- and lab-work. Using the WellDog technology, it required less than $200,000 and less than two weeks of field- and lab-work.

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